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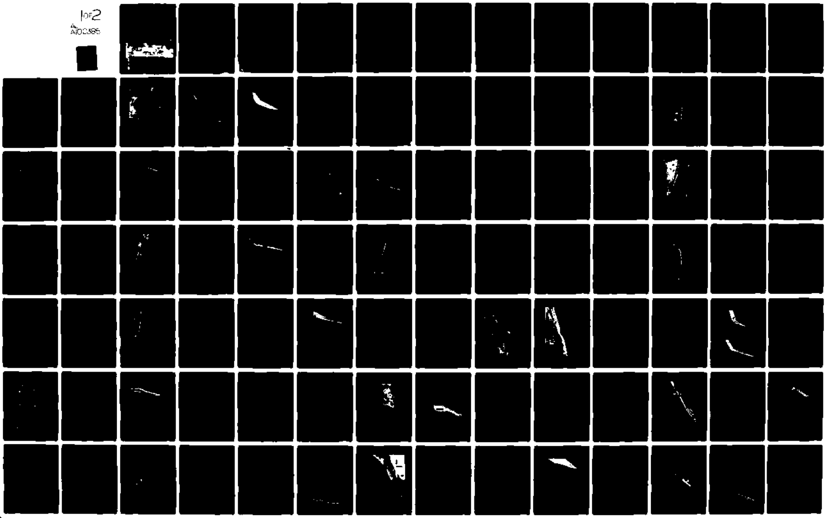

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BEACH NOURISHMENT TECHNIQUES

TECHNICAL REPORT H-76-13

BEACH NOURISHMENT TECHNIQUES

Report 3

TYPICAL U. S. BEACH NOURISHMENT PROJECTS USING OFFSHORE SAND DEPOSITS

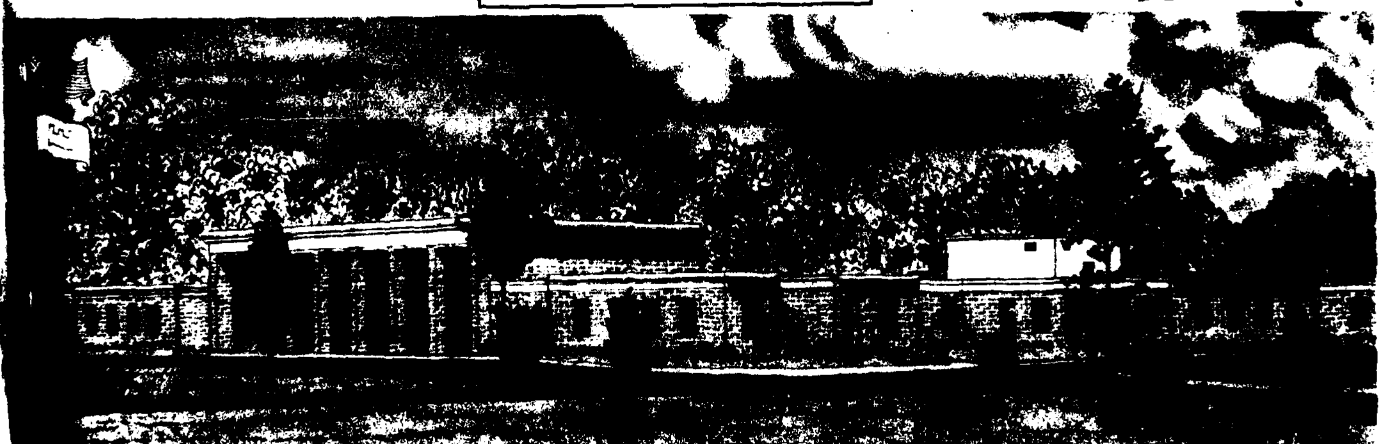
by

R. D. Hobson

Geotechnical Engineering Branch
U. S. Army Coastal Engineering Research Center
Fort Belvoir, Va. 22060

May 1981

Report 3 of a Series



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This report is a compendium of beach nourishment project characteristics for 20 typical U. S. shore segments for which the use of beach fill sediments from offshore borrow source areas has been suggested as a remedy for shore erosion. Data are provided to establish a basis for long-range planning of nourishment projects and systems. For each example project, the data provided consist of: history and description, location and bathymetry, fill and borrow site characteristics and specifications, design fill section, sediment grain size distributions, and fill calculations.

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PREFACE

The study reported herein was conducted using funds provided by the U. S. Army Engineer Waterways Experiment Station (WES) in conjunction with the Beach Nourishment Techniques Project. This project is funded by the Operations Division, Office, Chief of Engineers (OCE), under the auspices of the Investigation of Operations and Maintenance Techniques (IOMT) program. Mr. Tom Richardson was the WES Technical Monitor for the work.

The report was prepared by Dr. R. D. Hobson, Geotechnical Engineering Branch, Engineering Development Division, U. S. Army Coastal Engineering Research Center.

The author would like to thank the following Corps of Engineers District personnel for securing data required for this report and assisting the author in data searches through District files and records. Thanks go to Messrs. Gil Nersesian, New York; Curt Baskette, Norfolk; Lim Valianos, Wilmington; Frank Posey, Savannah; Jay Lockhart, Atlanta; Andy Hobbs, Jacksonville; Lell Harris, formerly of Jacksonville; Walt Burdin, Mobile; Dan Muslin, Los Angeles; Jerry Stadler, Chicago; and Miss Joan Pope, Buffalo.

Directors of WES during the conduct of this study and the preparation and publication of this report were COL John L. Cannon, CE, and COL Nelson P. Conover, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

BEACH NOURISHMENT TECHNIQUES

TYPICAL U.S. BEACH NOURISHMENT PROJECTS USING OFFSHORE SAND DEPOSITS

PART I: INTRODUCTION

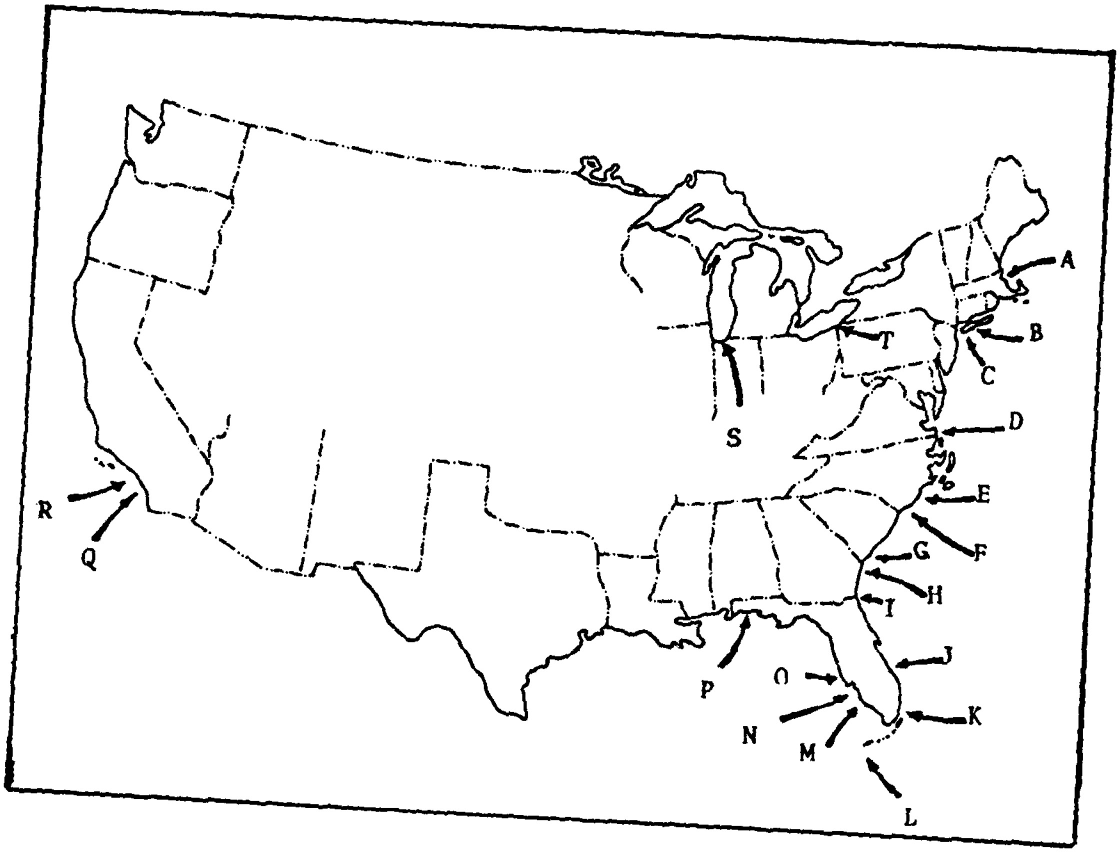
Background

1. This report is part of a series prepared under the auspices of the Beach Nourishment Techniques project. The purpose of this project is to evaluate, recommend, and develop techniques, procedures, and equipment for use in future beach nourishment work. This report is one of three aimed at quantifying the engineering characteristics of beach nourishment projects representative of the range of conditions encountered in the continental United States, especially those projects where offshore sand borrow sources appear necessary and/or feasible.

2. This report describes the sedimentary and physical features of 20 selected offshore beach nourishment projects (Figure 1). A companion report gives the average wave climate at 10 of these 20 example projects. Another report summarizes and interprets the results of these two reports from the standpoint of offshore dredging system requirements. Various types of offshore dredging systems, both existing and proposed, were described in the first Beach Nourishment Techniques report (Richardson 1976).

Criteria for Project Selection

3. The shore segments selected for study were those for which beach fill was recommended as an engineering solution to combat critical erosion caused by normal littoral processes acting over a long period of time, by the short-term action of storm events, or a combination of both. In addition, all are shore segments for which Federal projects or



LEGEND

A. MASSACHUSETTS BAY, MA
B. WESTHAMPTON BEACH, NY
C. ROCKAWAY BEACH, NY
D. VIRGINIA BEACH, VA
E. CAROLINA BEACH, NC
F. BRUNSWICK COUNTY, NC
G. HUNTING ISLAND, NC
H. TYBEE BEACH, GA
I. NASSAU COUNTY, FL
J. INDIAN RIVER COUNTY, FL
K. DADE COUNTY, FL
L. KEY WEST, FL
M. CHARLOTTE COUNTY, FL
N. LIDO KEY, FL
O. TREASURE ISLAND, FL
P. PANAMA CITY, FL
Q. NEWPORT BEACH, CA
R. REDONDO BEACH, CA
S. INDIANA DUNES, IN
T. PRESQUE ISLE, PA

Figure 1. Beach fill projects location map

studies have been authorized, or which are publicly owned and classified as "critically eroding" by the National Shoreline Study (Department of the Army, Corps of Engineers 1971) or by an update of the Shoreline Study done under the Beach Nourishment Techniques Project. Projects selected using the criteria above would be too numerous for inclusion in this report. Therefore, the following additional criteria were applied in order to select a more reasonable number of project sites:

a. Quality of the textural data describing native beach and potential borrow sediments.

b. Location of possible sites along the U.S. shoreline (including the Great Lakes) for which adequate textural data are available.

Quality of textural data

4. Two types of beach fill models are currently used by the Corps of Engineers to predict (a) overfill requirements to achieve the volumetric dimensions of a project when less-than-suitable fill sediments are available and (b) the frequency with which renourishment will be required. Both models are mathematical (James 1975) and require descriptions of the textural properties of the native beach and potential borrow sediments as input. These properties are usually the mean grain size and sorting of the grain size distribution (gsd) of each sediment source as expressed in phi size units (Krumbein 1938). For both models, the gsd of the native beach sand is considered as standard and is assumed to reflect a dynamically stable response of the sediments to the processes active along that coastal segment. Comparison of the standard with a potential borrow sediment gsd is used to calculate the overage needed to compensate for expected losses of the finer sediment sizes winnowed from the fill by wind and hydraulic action shortly after placement on the beach. For renourishment, comparison of the gsd's yields the relative frequency of sand placement needed to maintain project dimensions if the sand to be used is texturally dissimilar to native sediments.

5. The most important factor affecting the reliability of model predictions is the quality of the available textural data describing both native and borrow sediments. Each sediment source is described

by "composite gsd's" which are averaged grain size distributions of suites of samples collected from the active beach profile and from cores (usually) of potential borrow sediments. To obtain representative composites, sampling schemes must be employed that adequately represent known components of textural variation. For beach sediments these components include, in order of importance, variations along the profile lines, along the shore, with depth, and with season (Hobson 1977). For borrow sediments, variations occur with depth and between core samples.

6. The textural data for each project presented herein satisfied the following sampling requirements:

a. Native beach sediments.

(1) Samples were collected across several profile lines.

(2) The profile lines were systematically sampled across both the offshore and onshore segments of the active beach.

b. Potential borrow sediments.

(1) Cores, rather than surface samples were obtained.

(2) Several cores were taken from most potential areas.

(3) Multiple sediment samples were collected from most cores.

These few sampling requirements reduced the number of possible projects for this report to an easily manageable size.

Location of sites

7. One purpose of this report is to include projects for shore segments that are representative of the total U.S. shoreline. This purpose was easily satisfied for some areas like the Florida coastline where beach fill projects are numerous and adequate textural data were available. In other areas such as along the Pacific Ocean, few fill projects utilizing offshore borrow have been planned or accomplished. For these areas, all projects were included for which the required textural data were available, whereas only those projects with the best developed data were included for areas with numerous choices.

8. Finally, it should be noted that the use of offshore borrow sources is a relatively new practice, and that in some areas the only

offshore information is available through the Sediment Inventory Program of the U.S. Army Coastal Engineering Research Center (CERC), Ft. Belvoir, Va. This ongoing program is conducted, by request, on a regional basis and the offshore data obtained are not intended to be as detailed as would be required for a specific local fill project. Nevertheless, these data have been used in this report to develop borrow source area composites for certain shore segments where no other offshore data were available. These segments are Nantasket and Revere Beaches on Massachusetts Bay, Mass. (Meisburger 1976), Carolina Beach, N. C. (Meisburger 1977), and Newport Beach, Calif. (Field 1974).

Organization of Report

Presentation of data

9. The information concerning each selected project is classed into the following areas:

- a. Beach fill project description (narrative).
- b. Location and bathymetry (map figure).
- c. Project specifications (table).
- d. Design profile of beach fill section (figure).
- e. Composite grain size distributions (table).
- f. Beach fill model calculations (table).

Beach fill project description

10. This section contains a brief history of the project area and discusses problems leading to the authorization of studies and engineering works. This section also includes general descriptions of the area to be filled and of potential borrow areas. The performance of completed projects is evaluated when possible. No attempt is made to document all information concerning an area, but the documents are referenced that were used to compile the data presented in the accompanying figures and the related table.

Location and bathymetry

11. The maps of this area summarize the general spatial relationships between the project area and proposed borrow source areas.

Bathymetric detail is generalized to provide a "feel" for the kinds of local conditions encountered by dredging and transportation systems. National Ocean Survey (NOS) charts were used to prepare the maps, and thus distance scales are in both kilometres and nautical miles, while depths are in feet.

Project specifications

12. This topic is covered by a table divided into three sections that contain characteristics of the beach fill project, borrow site, and additional project considerations, such as estimated cost and special features. This table is intended to summarize engineering requirements and environmental conditions for each project-source combination.

Design beach fill section

13. Data for these engineering drawings come from the sources referenced in the Beach Fill Project Description section, but each cross section has been redrafted to a common format to simplify comparison of projects. Distances and elevations have been converted to metres from the original U.S. customary units.

Composite grain size distributions

14. The tables of this information show the cumulative percent of sediment coarser than a particular size in the composite gsd's for native beach and potential borrow sediments. The number of samples used to compute each composite is shown in parentheses at the top of the column containing the gsd for each sediment source. The gsd's are characterized for beach model calculations by the phi mean and sorting parameters. Also included are millimetre equivalents of each phi size and of the phi means.

Beach fill model calculations

15. These calculations were performed following procedures described in Chapter 5 of the Corps of Engineers Coastal Engineering Research Center's Shore Protection Manual (SPM) (1977). The tables include the adjusted fill factor (R_A) and renourishment factor (R_J) for each beach-borrow source combination. These are the factors recommended by the Corps of Engineers for determining initial nourishment and subsequent renourishment requirements. Both factors can be calculated directly

using the composite gsd percentages or can be determined using graphs with axes that compare sorting ratios with the scaled differences between the phi means of the native and borrow sediments (James 1975).

Model calculation interpretations

16. The interpretation of beach fill model calculations was made as follows:

a. Fill factors. Fill factors (R_A) have possible values of 1 and greater. A value of 1 indicates that an equal volume of borrow or native sediment is required to achieve project dimensions. Values greater than 1 indicate a need for excess borrow sediment to compensate for early winnowing losses from the fill. For example, a fill factor value of 1.7 indicates that the volume of that particular borrow sediment would need to be 1.7 times as great as the project design volume. Fill factors of value greater than 4 or 5 indicate that the borrow material would probably be unsuitable as fill.

b. Renourishment factors. Renourishment factors (R_J) can range in value from nearly zero to 10 or more. Values less than 1 indicate that the borrow material is more stable than native beach sediments and thus less frequent nourishment is anticipated when it is used as fill. For example, an R_J equal to 0.7 predicts that the borrow material would last 1.3 (the reciprocal of 0.7) times longer as fill than would nativelike sediments. R_J values greater than 1 identify borrow sediments that are less stable than native beach sediments. Thus, the project would require more frequent renourishment than if nativelike sediments had been used as fill. Values of 1 predict equal performance of either native or borrow sediments.

PART II: BEACH FILL PROJECTS

Massachusetts Bay, Mass.

17. Revere and Nantasket Beaches are located in the towns of Revere and Hull, Mass. (Figures 2 and 3), along the shore of Massachusetts Bay. Both sites are exposed to direct wave attack from the bay during storms, Revere from the east and southeast and Nantasket from the east and northeast. The problem existing at these beaches is general erosion due primarily to the advanced development of the shore and the erection of protective structures. The development and structures have essentially eliminated sources of littoral material which formerly allowed the shore to be in dynamic equilibrium with natural transportation processes.

Revere Beach

18. Revere Beach is perhaps the most popular and widely used beach in Massachusetts (U. S. Army Engineer Division, New England 1968). Revere Beach is a public beach with extensive development including seawalls, bulkheads, pavilions, and an amusement park. Losses of sand from the beach due to longshore and offshore movement average about 3100 m^3/year. During frequent serious storms, waves breaking on the massive seawalls have been observed to increase losses from the backshore by scouring from the seawall toe to some distance seaward.

19. In 1949, the U.S. Army Engineer Division, New England,* recommended adoption of a beach protection project for Revere Beach which called for placement of 402,000 m^3 of beach fill (Figure 4). This project was authorized in 1954 by the 1954 River and Harbor Act. In that same year, approximately 132,000 m^3 of sand was dredged from a source located about 0.8 km offshore and placed along the southern 2.6 km of the beach. Computations made immediately after nourishment indicated losses of about 50 percent from the finer size fractions of the fill.

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* For brevity, further references to Corps of Engineers organizations will be by Division or District name only.

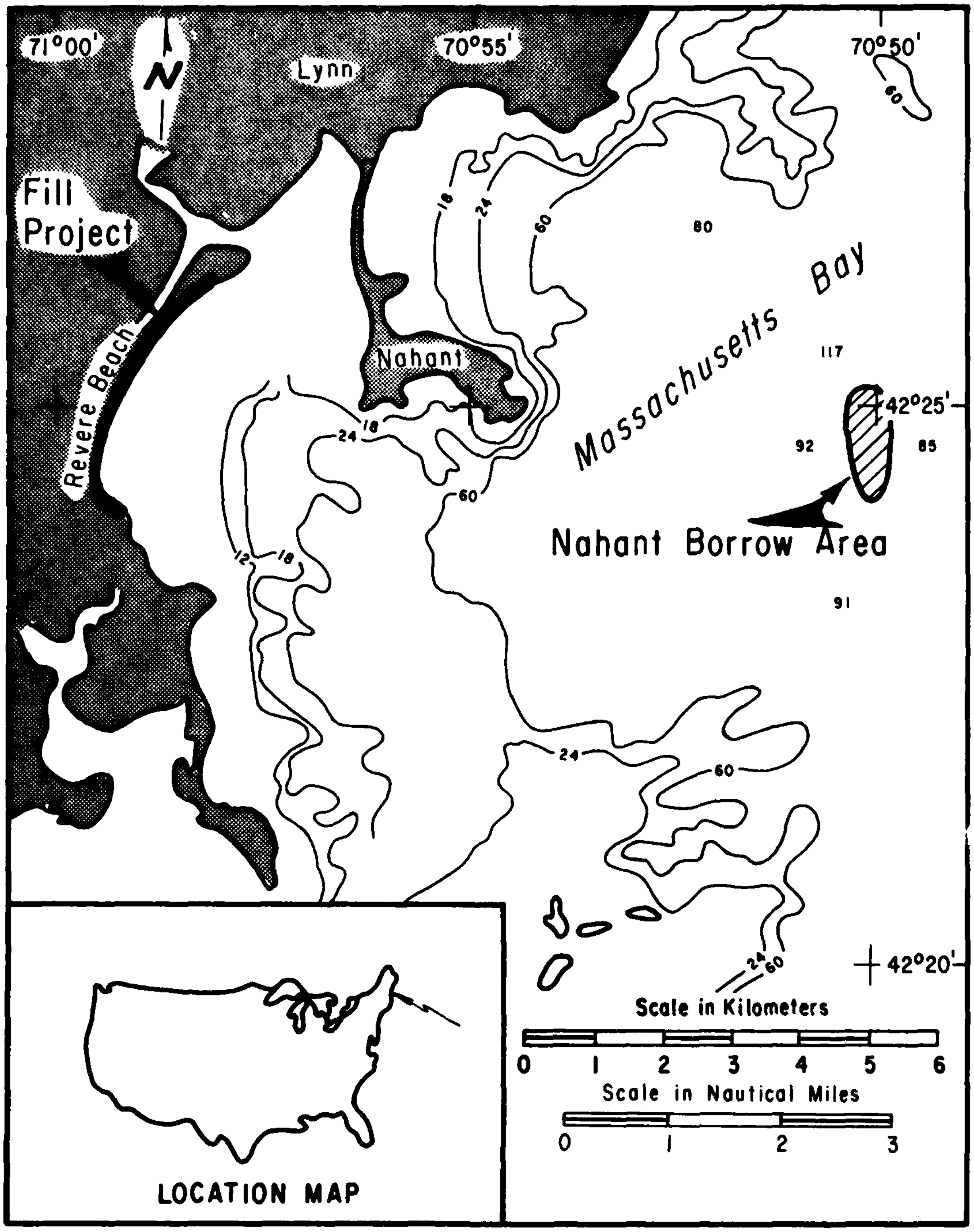

Figure 2. Location and bathymetry, Revere Beach, Mass. (depth contours in feet; to convert feet to metres multiply the number of feet by 0.3048)

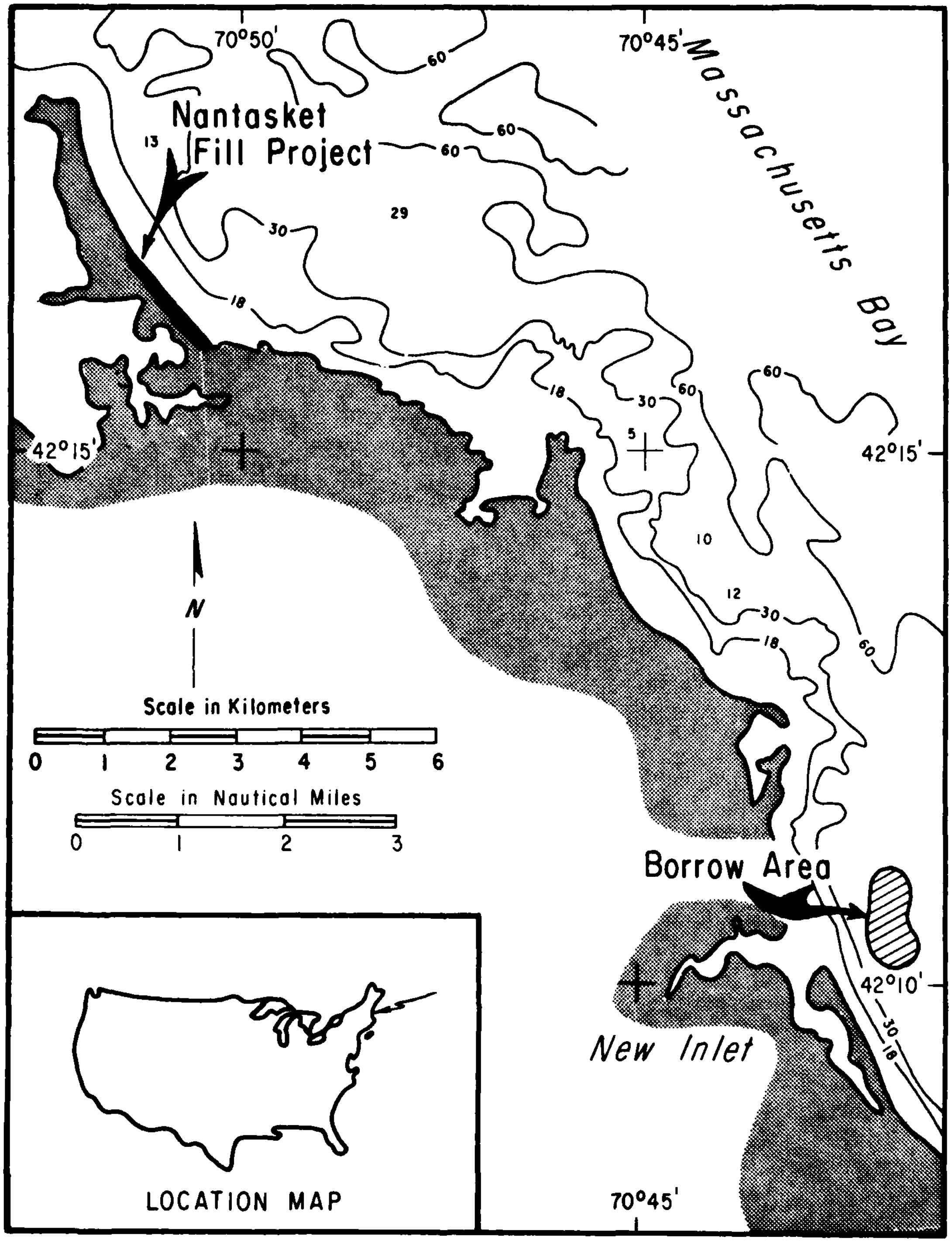

Figure 3. Location and bathymetry, Nantasket Beach, Mass.
(depth contours in feet)

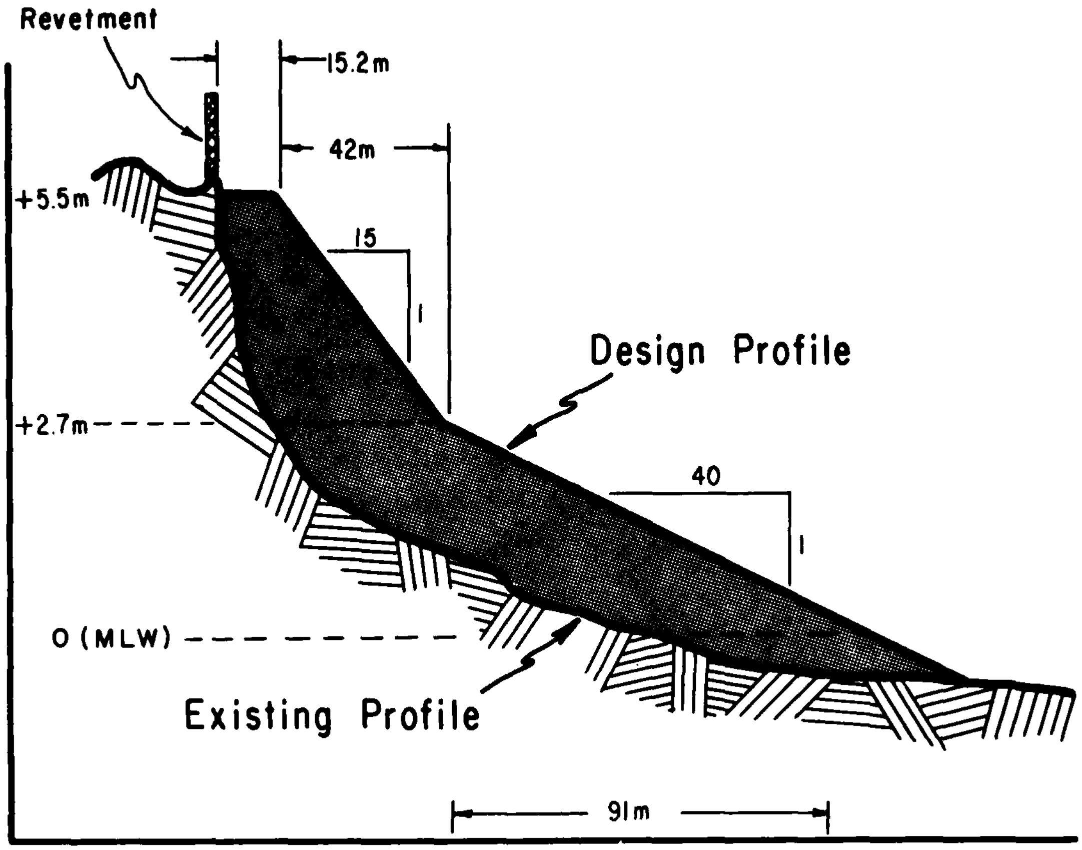

Figure 4. Beach fill section, Revere Beach, Mass.

Project construction was then discontinued due both to the fineness of this borrow and to the inability to hold sand at the desired location. A Beach Erosion Control (BEC) study completed in 1968 recommended placement of additional beach fill to create a berm elevation of +5.5 m above mean low water (mlw) and to widen the beach by 56 m at the high water line (mhw). To date, the project has not been undertaken, due in part to a lack of suitable and available fill material.

Nantasket Beach

20. Nantasket Beach ties together several glacial drumlins and forms a complex tombolo. It is constantly exposed to surf action and is also faced with a deficiency of replenished littoral sediment. Annual sand losses along this 2.1-km beach (U. S. Army Engineer Division,

New England 1968) are 5400 m^3/year. Unlike Revere Beach, Nantasket Beach was characterized as stable in the 1949 cooperative BEC report and thus no nourishment was authorized in 1954 (or since), although erosion problems were apparent to local residents. The composition of the beach sediment is a mixture of glacially derived small cobbles and fine sand (often in a 1:1 ratio). Frequent storms separate these components by moving the fine sand offshore and leaving the cobbles as a lag, or armor blanket, which is subsequently trucked away during annual "cleanup" operations. Thus, losses by storm and by man combine to create the annual volume losses and decrease the beach level.

21. The offshore area of Massachusetts Bay is characterized by numerous types of relict glacial deposits such as morainal, outwash, and beach and river channel sediments. Extreme textural variation is commonplace within and between deposit types making the reevaluation of potential offshore borrow sites difficult. Offshore areas have not been investigated enough in detail to adequately develop their fill potential for nourishing Revere and Nantasket Beaches. Characteristics of the Nahant and New Inlet borrow sites are shown in Tables 1, 2, and 3. Tables 2 and 3 were developed during a regional sand inventory program conducted by CERC in Massachusetts Bay (Meisburger 1976). Further investigations of both areas would be required before recommending them as beach fill sources. Native beach composite gsd's (Table 3) are adequate for project design purposes.

Westhampton Beach, N.Y.

22. Westhampton Beach, which is 9 km long, lies approximately midway along the nearly straight barrier island chain extending 97 km westward from Montauk Point on the eastern tip of Long Island to Fire Island Inlet, which connects the Atlantic Ocean with Great South Bay. Shinnecock Inlet lies 13.6 km east of Westhampton Beach, while Moriches Inlet is 2.3 km to the west. These are the only major inlets along the entire barrier system.

23. In the past, storms and hurricanes have been responsible for

Table 1

Project Specifications, Massachusetts Bay, Mass.

Beach and Fill Characteristics

	Revere Beach	Nantasket Beach
Initial fill volume	639,100 m^3	539,000 m^3
Renourishment volume	15,400 m^3/year	15,400 m^3/year
Fill length	4.0 km	2.1 km
Fill elevation (above mlw)	5.5 m	5.2 m
Beach width increase	56 m at mhw	56 m at mhw
Average volume loss (long term)	3,100 m^3/year	5,400 m^3/year

Borrow Site Characteristics

	New Inlet	Nahant
Site area	0.5 km^2	0.4 km^2
Average water depth	15.0 m	27.0 m
Average thickness	3.2-m cored	2.0-m cored
Sediment volume	1,600,000 m^3 (min)	Not known
Distance to Revere Beach	35.0 km	12.5 km
Distance to Nantasket Beach	20.0 km	19.0 km
Additional exploration	Required	Required
Other	Ancestral channel fill of North River	

Additional Considerations

Initial cost	Not known
Annual cost	Not known
Monitoring planned	No project to date
Other	Borrow sources glacial in origin, wide variety of particle types and sizes

Table 2

Composite Grain Size Distributions, Massachusetts Bay, Mass.

Size mm	Size ϕ	Revere Beach (33 Samples)	Nantasket Beach (24 Samples)	Nahant Borrow (3 Samples)	New Inlet Borrow (17 Samples)
38.00	-5.25		6.9		
24.25	-4.60		18.0		
19.02	-4.25	0.0	21.8		
11.31	-3.50	0.1	26.2		
4.75	-2.25	1.7	28.3		0.0
2.00	-1.00	3.1	31.4	0.0	0.4
0.84	0.25	4.6	32.4	0.2	3.0
0.42	1.25	6.5	35.6	27.0	20.0
0.35	1.50	15.0	67.8	52.8	33.0
0.15	2.75	35.7	87.0	95.2	94.5
0.07	3.75	96.3	99.6	100.0	98.2
0.06	4.00	100.0	100.0	100.0	98.6
Phi mean		2.50	-1.08	1.67	1.77
Mean (mm)		0.18	3.48	0.31	0.29
Phi sorting		0.90	3.58	0.85	0.59

Table 3

Beach Fill Model Calculations, Massachusetts Bay, Mass.

	Nahant Borrow	New Inlet Borrow
Revere Beach		
Fill factor (R_A)	1.00	1.00
Renourishment factor (R_J)	0.42	0.14
Nantasket Beach		
Fill factor (R_A)	>7.00	>7.00
Renourishment factor (R_J)	3.80	>7.00

"opening" inlets across the barrier while longshore processes have clogged and "closed" these ephemeral openings. Moriches Inlet was opened by a storm in 1931 and was stabilized in 1947 by construction of long entrance structures. Shinnecock Inlet, opened by a hurricane in 1938, was stabilized by 1952 with jetties, allowing boats access to Great Peconic Bay. These structures have generally interrupted the westward transport of sand from Montauk Point. As much as 80 percent of this transport is estimated to have been diverted into the bay areas, forming huge flood tidal deltas. These changes have created serious beach erosion problems in starved segments down the coast. Recession rates at Westhampton averaged about 0.3 m^3/year prior to inlet stabilization and are estimated to have increased to about 2.1 m/year since then (U. S. Army Engineer District, New York 1958).

24. Westhampton's erosion problems have also been accelerated by the construction of groins and the leveling of natural dunes for home construction. A system of 11 groins was completed along the easternmost (updrift) segment of Westhampton in 1966 to combat erosion losses caused by major storms in 1962. No fill was provided for the groined compartments, and thus they created further starvation and accelerated erosion down the coast. In 1970, four more groins were built downdrift of the first field, and although fill was placed in the groined compartments, erosion continued directly downdrift. Since 1970, intense state and local jurisdictional disputes regarding the solution to Westhampton's erosion problems have been waged with no results. On 3 December 1974, the ocean broke through the barrier at the western ungroined end of Westhampton Beach and created the first new inlet since 1938 (Heikoff 1976).

25. The Corps of Engineers has undertaken a number of studies in the area since 1914. The most significant is a cooperative Beach Erosion Control and Hurricane Protection (BEC/HUR) study (U. S. Army Engineer District, New York 1958) authorized under the River and Harbor Act of 1930. In this study the District Engineer made the following recommendations for the entire 97-km-long barrier: (a) that the beach be renourished to a 30-m-minimum width at 4.2 m above mean sea level (msl),

(b) that dunes be restored to an elevation of 6.1 m and be planted with appropriate grasses, and (c) that 50 groins be built after nourishment along the shore, if and when experience indicated their need.

26. The preceding recommendations (Table 4) have not been carried out, but in 1975 the New York District contracted for the evaluation of beach and offshore borrow source sediments in anticipation that the project would be constructed. Twenty-eight core samples were taken in the area offshore of Westhampton (Figure 5). Textural evaluations of samples from the cores and the beach indicated two areas with promising beach fill potential. These are located in the western and central portions of the area investigated and are identified as borrow areas A and B, respectively, in Figure 5. Composite gsd's from these areas and from the groined and ungroined portions of the study beach (Table 5) are compared in Table 6 to determine beach fill requirements of the design profile (Figure 6).

Rockaway Beach, N.Y.

27. Rockaway Beach is within the Borough of Queens, New York City, and occupies the easterly 9.6 km of the 16-km-long peninsula that separates the Atlantic Ocean and Jamaica Bay (Figure 7). The beach has evolved over the past century in response to multiple phases of artificial nourishment. Recent erosion and storm damage conditions prompted authorization in 1964 of a multiple purpose beach erosion control and hurricane protection project for the area (Table 7, Figure 8). The project was to include construction of a 5.5-m-high floodwall along the barrier, a 5.5-m-high surge barrier across the entrance to Jamaica Bay, and beach nourishment (U.S. Army Engineer District, New York 1974). Severe erosion conditions in 1973, caused by a greater than normal number of storm events that occurred during the period of 1961-1973, resulted in reauthorization of the beach nourishment phase of the project. The first portion of this three-phase restoration work was completed along a central 4.8-km segment during the summer of 1975. The second and third phases of this project were completed in 1976 and 1977,

Table 4

Westhampton Beach, N.Y.

Beach and Fill Characteristics

	Westhampton Beach (Groined)	Westhampton Beach (Ungroined)
Initial fill volume	3,318,000 m^3	2,550,000 m^3
Renourishment volume	53,200 m^3/year	103,500 m^3/year
Fill length	2.8 km	5.2 km
Fill elevation above mlw	4.2 m	4.2 m
Beach width increase	30 m at 4.2-m el	30 m at 4.2-m el
Average volume loss	53,200 m^3/year	103,500 m^3/year

Borrow Site Characteristics

	Western Borrow A	Central Borrow B
Site area	2.1 km^2	1.2 km^2
Average water depth	12.0 m	12.0 m
Average thickness	6.1 m	6.1 m
Sediment volume	12,800,000 m^3	7,320,000 m^3
Distance from project	1.5-11.0 km	1.5-11.0 km

Additional Considerations

	Groined	Ungroined
Initial cost	$11,698,100	$8,887,500
Monitoring planned	Yes	Yes

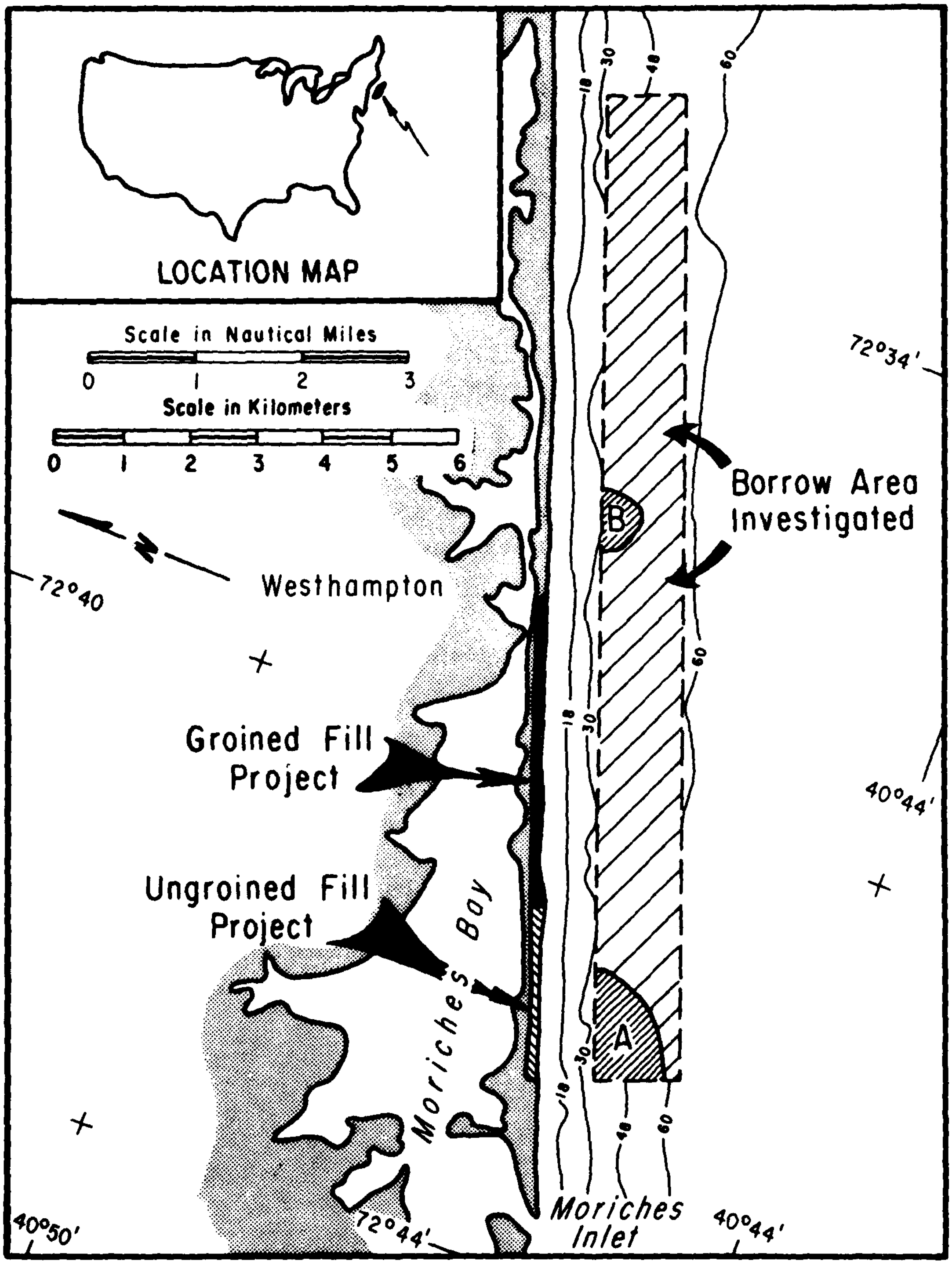

Figure 5. Location and bathymetry, Westhampton Beach, N.Y. (depth contours in feet)

Table 5

Composite Grain Size Distributions, Westhampton, N.Y.

Size mm	Size φ	Native Beach Groined (26 Samples)	Native Beach Ungroined (24 Samples)	Western Borrow (4 Cores)	N. Central Borrow (1 Core)
12.13	-3.60	0.0	0.0	5.8	4.0
4.75	-2.25	0.8	2.2	9.3	9.0
2.00	-1.00	4.0	4.3	12.5	10.0
0.60	0.75	15.8	16.4	35.0	25.0
0.25	2.00	60.3	66.8	84.5	76.0
0.15	2.75	82.9	87.0	93.5	89.0
0.07	3.75	97.8	98.9	97.9	97.0
Phi mean		1.80	1.62	0.68	1.20
Mean (mm)		0.29	0.32	0.62	0.43
Phi sorting		1.05	0.98	1.35	1.20

Table 6

Beach Fill Model Calculations, Westhampton, N.Y.

	Western Borrow	N. Central Borrow
Groined Eastern Segment		
Fill factor (R_A)	1.00	1.02
Renourishment factor (R_J)	0.25	0.40
Ungroined Western Segment		
Fill factor (R_A)	1.00	1.00
Renourishment factor (R_J)	0.26	0.48

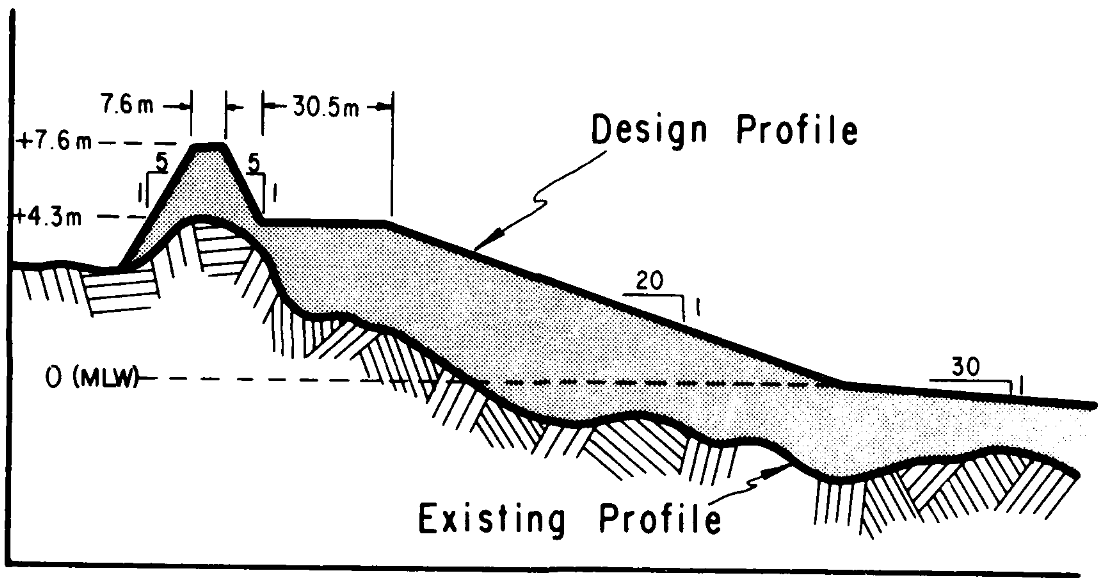

Figure 6. Beach fill section, Westhampton Beach

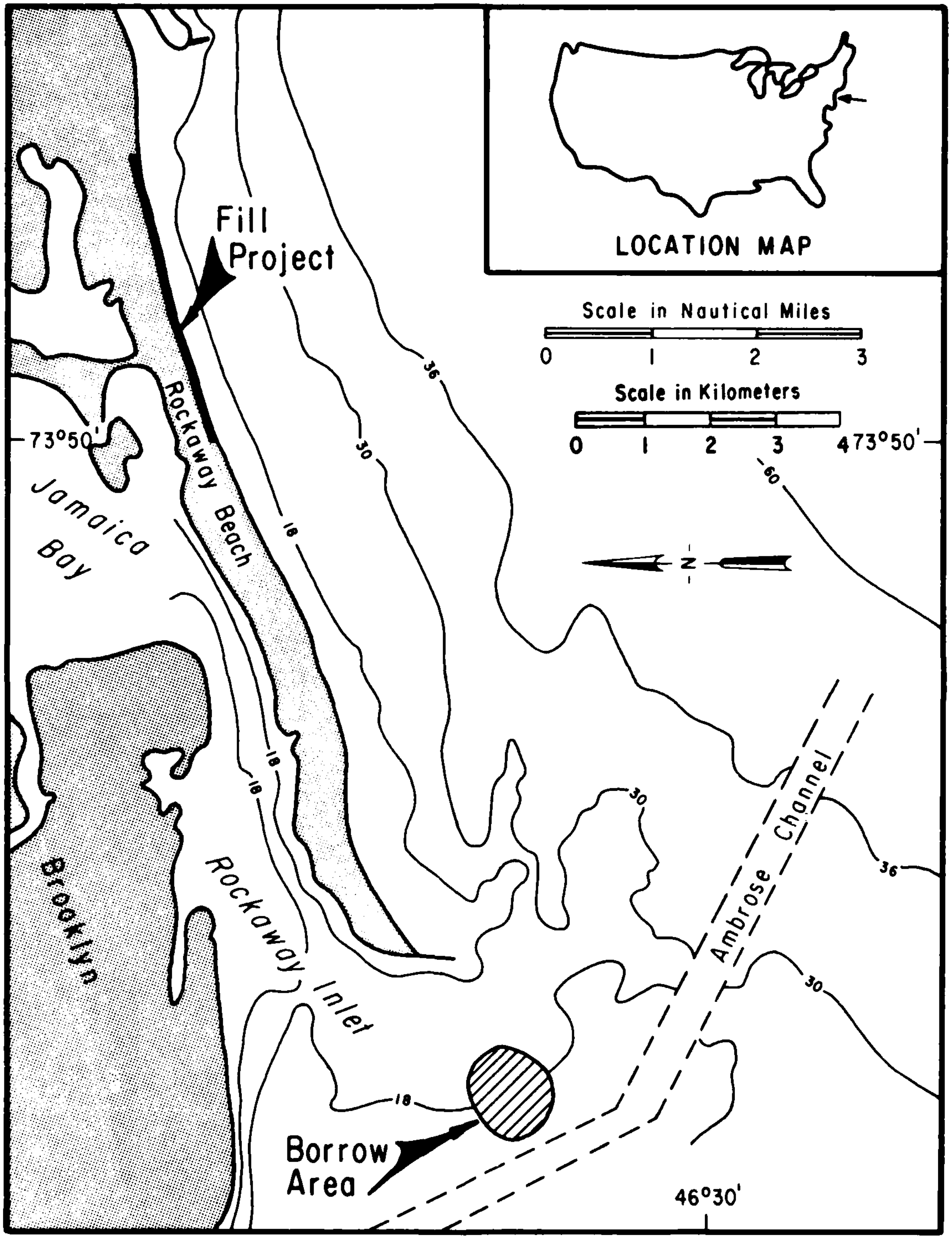

Figure 7. Location and bathymetry, Rockaway Beach, N.Y. (depth contours in feet)

Table 7

Project Specifications, Rockaway Beach, N.Y.

Beach and Fill Characteristics	
	Rockaway Beach
Initial fill volume	2,805,000 m^3
Renourishment volume	324,000 m^3/year
Fill length	4.8 km
Fill elevation (above mlw)	3.0 m
Beach width increase	30-m berm min.
Average volume loss	324,000 m^3/year
Average recession rate	0.8 m/year
Borrow Site Characteristics	
	East Bank Shoal
Site area	1.4 km^2
Average water depth	5.4 m
Average thickness	6.6 m
Sediment volume	8,411,000 m^3
Distance from project	13 km
Additional Considerations	
Initial cost	$9,388,366
Annual cost	$527,000
Monitoring planned	Yes

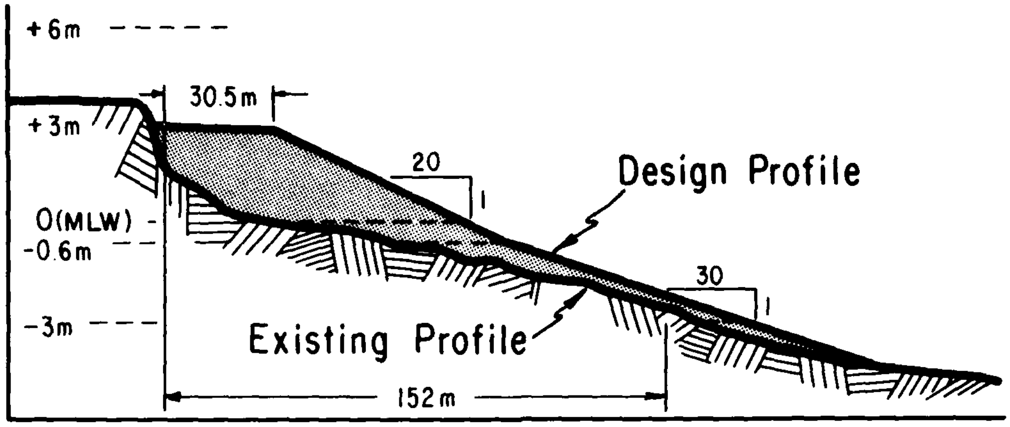

Figure 8. Beach fill section, Rockaway Beach, N.Y.

respectively. The Federal Government's share of the estimated 34.4 million dollar project, including periodic nourishment for a 10-year period, is 50 percent.

28. Three potential offshore borrow areas were investigated using geophysical and coring techniques. Based upon grain size comparisons of native beach and cored sediments, plus factors such as location, water depth, and sand thickness, a borrow area in East Bank Shoal was selected as the most suitable sand source for the first phase of nourishment. The method used by the contractor to complete this work was to load scow barges at the borrow site using the 600-mm-diam cutter suction dredge Puerto Rico, tow the scows 13 km through Rockaway Inlet to a rehandling station on the landward side of the barrier, fluidize the loads using high pressure water jets, pump the slurry through a pipeline laid across the barrier, and then hydraulically place the fill along the project beach. A total of 2,805,000 m^3 were placed in this manner. Fill volume was determined by surveying material in place on the beach within the elevation limits of +3 m to -5.5 m, sea level datum (mlw).

29. The native beach composite (Table 8) is the averaged gsd for the suite of prenourishment beach samples used as the "design sand" in the project General Design Memorandum (GDM) (U. S. Army Engineer District, New York 1974). The borrow composite is the averaged gsd of sand samples from cores No. 203 and No. 208 taken within the East Bank Shoal

borrow area. Textural data were obtained from the GDM and from the files of the New York District. Table 9 contains the beach fill model calculations.

Table 8

Composite Grain Size Distributions,

Rockaway Beach, N.Y.

Size mm	Size ϕ	Native Beach (6 Samples)	East Bank Shoal (3 Cores)
2.00	-1.0	3.6	1.2
1.41	-0.5	4.2	2.6
1.00	0.0	4.3	4.9
0.70	0.5	8.0	9.0
0.50	1.0	16.5	16.0
0.36	1.5	27.0	30.5
0.25	2.0	52.0	54.5
0.18	2.5	90.0	79.0
0.13	3.0	95.5	91.0
0.08	3.5	98.0	96.0
0.06	4.0	99.0	99.0
Phi mean		1.69	1.85
Mean (mm)		0.31	0.28
Phi sorting		0.72	0.86

Table 9

Beach Fill Model Calculations,

Rockaway Beach, N.Y.

Fill factor (R_A)	1.24
Renourishment factor (R_J)	1.00

Virginia Beach, Va.

30. Virginia Beach is the primary public beach fronting the Atlantic Ocean in the state of Virginia. Extending from Cape Henry at the mouth of the Chesapeake Bay to the North Carolina border (Figure 9), it is extremely valuable from both a recreational and economic standpoint. But, as is typical of most shorelines along the eastern seaboard, storms and erosion have resulted in extensive structural and economic losses. In 1954 the Federal Government participated in the restoration of 5.3 km of this shoreline between Rudee Inlet and 49th St. (U. S. Army Engineer District, Norfolk 1970). The restoration placed over 990,000 m^3 of sand on the beach. Then, in 1962, the Norfolk District became engaged in a joint program with the state and local governments for continual nourishment of this same shoreline to provide a 31-m-wide beach at elevation 1.6 m above msl (Figure 10, Table 10). Approximately 114,000 m^3 of suitable sand have been pumped onto the beach annually, primarily from inland borrow areas and the estuary of Lake Rudee, located at the south end of the project. However, the quality and quantity of these sources have rapidly diminished. This depletion of existing sand sources, coupled with growing public concern for conservation of the estuarine environment, resulted in an immediate need for alternative sources.

31. Since the Corps of Engineers is also responsible for maintaining the Thimble Shoals navigation channel (Figure 9), a plan was developed to stockpile the fairly coarse grained, unpolluted maintenance material at Fort Story, Va., for use later on Virginia Beach, rather than dumping it in deep water offshore as had been common practice (U. S. Army Engineer District, Norfolk 1976).

32. Methodologies for pumpout/sand storage were developed based on experience gained at two previous Corps operations at Sea Girt, N.J., and Jacksonville, Fla. Both of these operations were accomplished with the hopper dredge Goethals, which has both bottom dump and pumpout capabilities. The Goethals when fully loaded displaces 9 m of water and can pump sand a maximum distance of 2.4 km. Due to the flat offshore profile fronting Virginia Beach, the loaded dredge could approach the beach

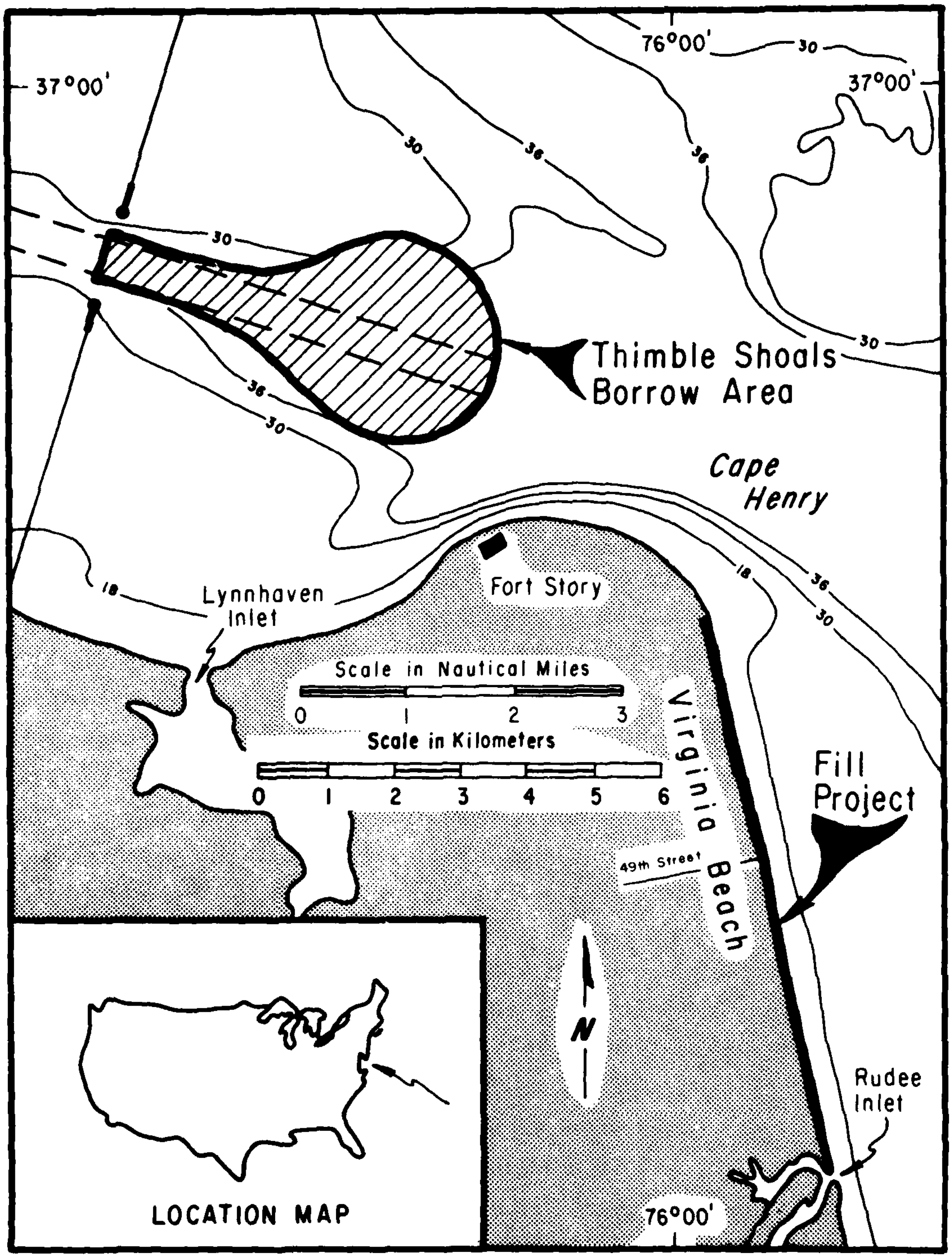

Figure 9. Location and bathymetry, Virginia Beach, Va. (depth contours in feet)

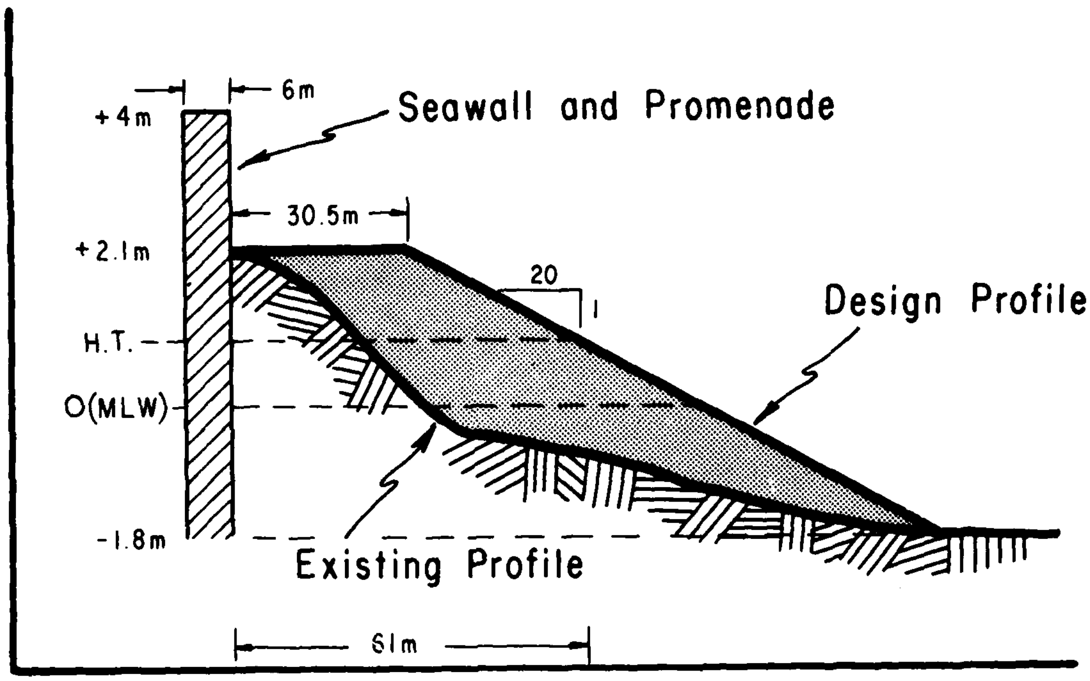

Figure 10. Beach fill section, Virginia Beach, Va.

Table 10

Project Specifications, Virginia Beach, Va.

Beach and Fill Characteristics	
Initial fill volume beach	1,900,000 m^3
Renourishment volume	102,000 m^3/year
Fill length	9.7 km
Fill elevation (above mlw)	
Beach berm	1.6 m
Storm dune*	4.9 m
Beach width increase	31-m berm
Average volume loss	143,800 m^3/year
Average recession rate	0.2 m/year
Borrow Site Characteristics	
Site area	1.5 km^2
Average water depth	14.0 m
Sediment volume	110,000 m^3/year dredged
Distance from project	2 km
Additional Considerations	
Initial cost	$16,900,000 (1970)
Annual cost	$1,287,100 (1970)
Monitoring planned	Yes
Other project features	Sheet pile bulkheads with stone toe protection

* Storm dune construction along 3.6 km of project.

itself no closer than 3 km and would thus require booster pump assistance. This was undesirable due to the open ocean exposure and high probable pumping costs. However, it is possible for the Goethals to approach quite close to Fort Story (notice relative closeness of contours on Figure 9). Therefore, it was decided to use Fort Story as a stockpile location for sand pumped out of the Goethals, and to rehandle the sand for placement on Virginia Beach.

33. The procedure used was to secure a DeLong Pier barge offshore of Fort Story, elevate it above the water, and secure a mooring barge alongside for the Goethals to tie to during pumpout operations. The mooring operation required the design of special fender units between the DeLong Pier and floating barge and the design of flexible, easily detached connectors to link the dredge with a submerged 71-cm-diam discharge pipe. The entire pumpout "terminal" was located offshore of Fort Story approximately 335 m. A 1.2-km-long discharge line ran from the terminal to the farthest limit of the sand storage site, a pumping distance well within the Goethals operating capabilities.

34. Dredge and pumpout operations began on 6 October 1974 and proceeded for almost 2 months. The project was quite successful, with over 342,000 m^3 of sand stockpiled and few shutdowns required. A beneficial result in terms of beach fill considerations was that about 37 percent of the sediment dredged was lost prior to storage (540,000 m^3 dredged versus 342,000 m^3 stored) and that these losses were predominately from the finer grain sizes, thus producing a coarser, more suitable fill material (Tables 11 and 12). Project costs charged to the Virginia Beach erosion control project were $551,926, which indicate a unit cost of $1.61 for each cubic metre of sand stockpiled.

35. Table 10 shows project specifications for Virginia Beach as presented in the 1970 BEC/HUR Feasibility Report (U.S. Army Engineer District, Norfolk 1970). The initial project requirements have been at least partially met by fills performed since 1970. Renourishment and erosion figures tabulated are considered to be generally representative of continuing project needs and probably can be satisfied by sediment

obtained every 2 or 3 years during maintenance dredging of the Thimble Shoals channel.

Table 11

Composite Grain Size Distributions, Virginia Beach, Va.

Size mm	Size ϕ	Native Beach (6 Samples)	Thimble Shoals (4 Samples)	Fort Story Stockpile (1 Sample)
2.00	-1.0	0.0	1.1	6.0
1.41	-0.5	0.0	2.5	10.0
1.00	0.0	0.1	4.8	16.0
0.71	0.5	0.8	10.1	28.5
0.50	1.0	3.5	17.5	43.5
0.35	1.5	16.0	35.0	63.0
0.25	2.0	37.0	68.0	84.0
0.18	2.5	50.0	78.5	93.5
0.13	3.0	62.5	90.0	97.7
0.09	3.5	86.0	95.0	99.4
0.06	4.0	98.4	97.0	100.0
Phi mean		2.48	1.64	1.00
Mean (mm)		0.18	0.32	0.50
Phi sorting		0.98	0.75	1.00

Table 12

Beach Fill Model Calculations, Virginia Beach, Va.

	Thimble Shoals	Fort Story Stockpile
Fill factor (R_A)	1.00	1.00
Renourishment factor (R_J)	0.58	0.25

Carolina Beach, N.C.

36. In April 1965, construction of a hurricane-protection and beach-erosion-control project was completed along 4.3 km of coastline fronting the town of Carolina Beach, N.C. (Figure 11, Table 13). An additional 4.5 km of the project (Figure 12) to continue south from the end of Carolina Beach were also authorized, but construction of this segment was deferred. The reason for deferment was the inability of local interests to finance a portion of the non-Federal share of project costs. Approximately 2,000,000 m^3 of sand was placed in a dune and beach configuration. After two years, about 43 percent of the in place fill had been eroded from the active beach profile. Losses from the northern 1.2 km of the project amounted to 56 percent and a recession of 43 m. In March 1967, another 274,000 m^3 of fill was placed along this northern segment, and a 123-m groin was built near the fill terminus for stabilization. However, by the following year, 56 percent of that fill had been lost and the shoreline returned to about the same position that existed prior to the fill work. Frequent storms and overtopping occurred during 1968 and 1969, again causing serious erosion to the northern project section and necessitating emergency nourishment. Funds were then authorized for an additional fill project as recommended by the Wilmington District (U. S. Army Engineer District, Wilmington 1970). This project was constructed in 1971 along the northernmost 0.4 km of the area and consisted of a sloping rubble wall built to a crest elevation of 4.6 m that was fronted by a beach fill containing 578,000 m^3 of sand. Erosion rates have still been higher than anticipated, although the 1971 fill sediments were of better quality than those used for the previous nourishments.

37. Erosion to the northern section of the project was attributed to: (a) distribution of the fill across the entire active profile to about -6.7 m elevation (mlw) rather than to the -1.2 m design-profile closing depth, (b) anticipated volumetric losses caused by reworking and removal of unstable fines from the fill sediments, and (c) a deficit of natural alongshore sediment transport caused by entrapment of littoral materials in and around Carolina Beach Inlet. Higher-than-expected

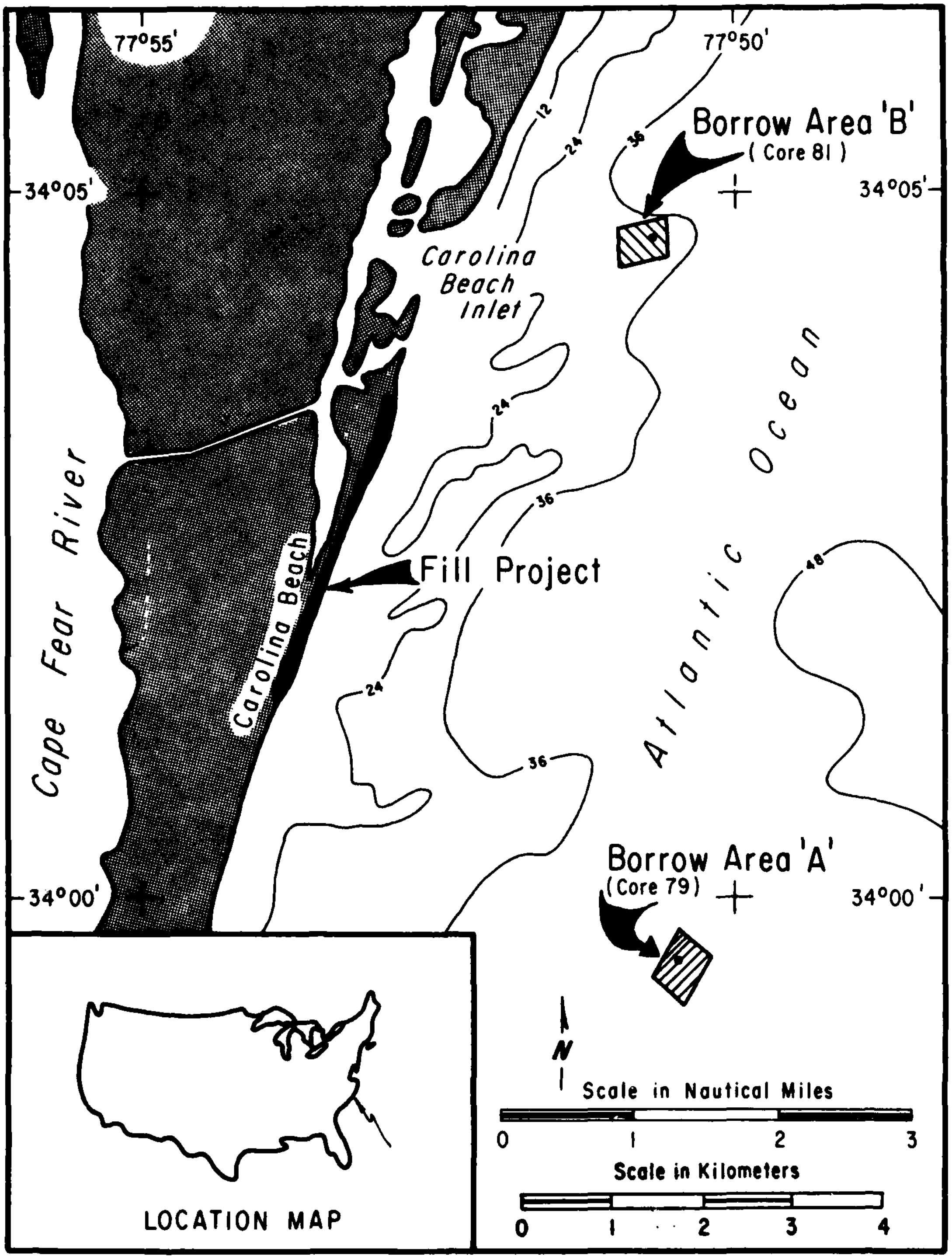

Figure 11. Location and bathymetry, Carolina Beach, N.C.
(depth contours in feet)

Table 13

Project Specifications, Carolina Beach, N.C.

Beach and Fill Characteristics

	Carolina Beach	
Initial fill volume	585,200 m^3	
Renourishment volume		
Borrow A source	43,000 m^3/year	
Borrow B source	30,800 m^3/year	
Fill length	3.0 km	
Fill elevation (above mlw)		
Beach berm	3.7 m	
Storm dune	4.6 m	
Beach width increase		
Berm width	15.2 m	
Dune width	7.6 m	
Average volume loss	30,800 m^3/year	
Average recession rate	0.3 m/year	

Borrow Site Characteristics

	Borrow A (Core 79)	Borrow B (Core 81)
Site area	Areas indeterminate at present	
Average water depth	13 m	12 m
Average thickness	6.1 m	2.4-m sand w/0.6- to 1.2-m over-burden
Sediment volume (m^3)	Volumes indeterminate at present	
Distance from project	8.5 km	4 km
Additional exploration	Needed in borrow areas	

Additional Considerations

	Carolina Beach
Initial cost	\$3,904,000 (1970)
Annual cost	\$388,000 (1970)
Other project features	Sand bypassing trap in Carolina Beach Inlet
Monitoring planned	Yes

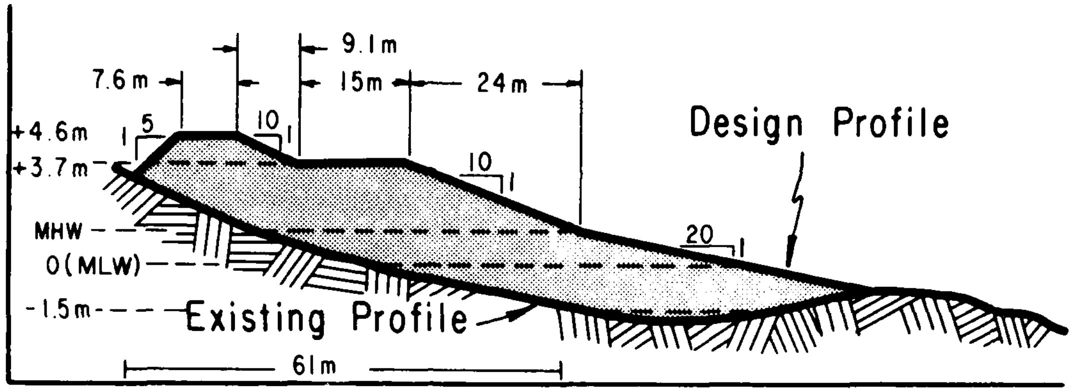

Figure 12. Beach fill section, Carolina Beach, N.C.

erosion to the southern portion of the project was concluded to be the combined result of (a) and (b) above.

38. Fill materials for the authorized portions of this project were obtained from: (a) the estuary at the south end of Carolina Beach Harbor in 1965, (b) the throat of Carolina Beach Inlet for the emergency fills in 1967 and 1970, and (c) the Cape Fear River for the 1971 project. Local offshore borrow sources had not been evaluated during construction of the projects discussed, but in 1971 CERC initiated a sand inventory program for the region (Meisburger 1977). Textural data for sediments cored at two locations (Figure 11) appear in Table 14 along with a native beach composite gsd. Borrow area B appears to contain suitable sands for beach nourishment purposes (Table 15) but additional exploration is required to adequately evaluate the potential of the area. Sediments from the Cape Fear River area identified by the Wilmington District still appear to be of better quality than those offshore at borrow area B.

Brunswick County, N.C.

39. The barrier islands of Brunswick County are within the Lower Cape Fear River region of North Carolina. A number of beach communities have been developed along these islands and the development has been

Table 14

Composite Grain Size Distributions, Carolina Beach, N.C.

Size mm	Size ϕ	Native Beach (17 Samples)	Borrow A Core 79 (4 Samples)	Borrow B Core 81 (4 Samples)
2.00	-1.0	0	0	0
1.41	-0.5	0.5	0	0.5
1.0	0	2.2	0	4.2
0.71	0.5	10.5	0.2	19.2
0.5	1.0	28.2	3.2	42.0
0.35	1.5	47.2	9.8	65.0
0.25	2.0	61.9	43.1	82.6
0.18	2.5	80.5	82.5	93.8
0.12	3.0	87.6	99.7	98.2
0.07	3.5	94.3	100.0	99.7
0.06	4.0	98.2	100.0	100.0
Phi mean		1.75	2.08	1.25
Mean (mm)		0.29	0.24	0.42
Phi sorting		1.05	0.43	0.80

Table 15

Beach Fill Model Calculations, Carolina Beach, N.C.

	Borrow A	Borrow B
Fill factor (R_A)	1.40	1.00
Renourishment factor (R_J)	1.30	0.50

accompanied by increased erosion problems, particularly to the south Brunswick coastline along Yaupon and Long Beach beaches. These two beaches extend east for approximately 14.5 km along Oak Island from Lockwood's Folly Inlet (Figure 13). Long-term erosion rates range from 1.7 m/year at Yaupon Beach at the west to 1.1 m/year at Long Beach.

40. A GDM prepared in 1963 by the Wilmington District considers 19 plans of action for the area (U. S. Army Engineer District, Wilmington 1973). Optimization procedures were used to consider factors of shoreline and hurricane history, wind and wave climate, shore processes, environmental impact, and recreation and economic aspects of the area. In addition, 170 sand samples were collected from along 10 beach profiles and 750 samples were obtained from 79 cores to describe native beach sediments and to evaluate potential borrow material for beach nourishment. The plan designated "BTG" in the GDM was selected as the most cost effective for the needed protection from hurricanes and beach erosion, as well as being acceptable to state and local interests.

41. This plan (Table 16, Figure 14) consists of an initial placement of 9,123,000 m^3 of fill, plus additional fills of 807,000 m^3 placed every third year at two feeder beach locations. The fill would be used to construct a 4.0-m-high back dune and to widen the 3.7-m-high storm berm by 15.2 m. In addition to the fill, plan BTG calls for construction of a timber bulkhead at Yaupon Beach, a 274-m-long rock revetment at Long Beach, and groin fields at the east and west margins of the project.

42. Nine potential borrow areas were considered, and, of these, sediments from Lockwood's Folly Inlet and from the Yellow Banks areas of the mainland were determined most suitable. Materials found in Middle Ground Shoal at the mouth of the Cape Fear River (identified as Borrow Area in Figure 13 and Table 17) were of the best quality for renourishment purposes but were considered too expensive because of high equipment mobilization-demobilization estimates. Use of the inland Yellow Banks area was recommended in the GDM, but the Middle Ground sediments are evaluated here as being more representative of offshore borrow materials for the area. The Lockwood's Folly Inlet sediments are not considered because of the small volume available.

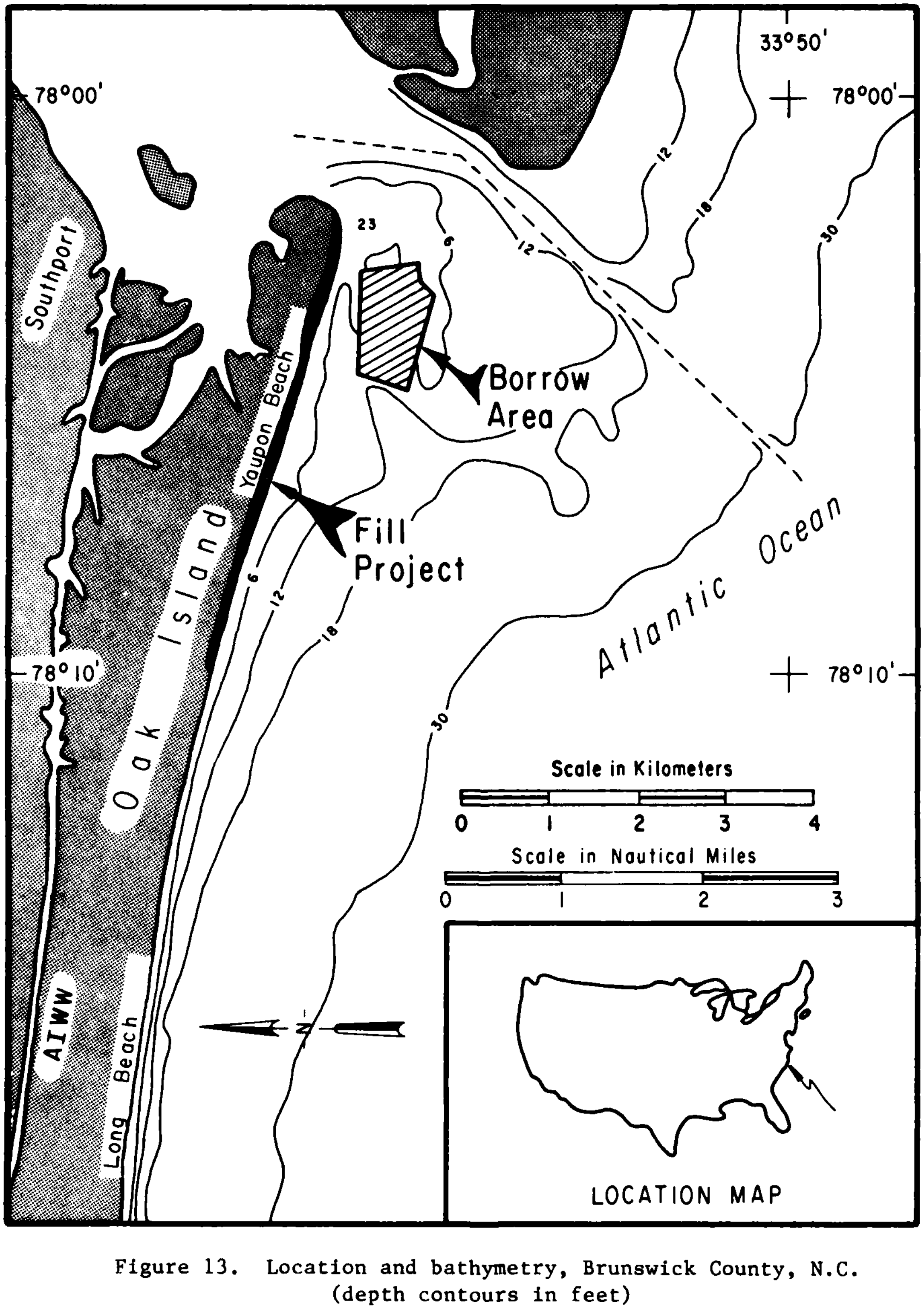

Figure 13. Location and bathymetry, Brunswick County, N.C. (depth contours in feet)

Table 16

Project Specifications, Brunswick County, N.C.

Beach and Fill Characteristics	
Initial fill volume	9,123,000 m^3
Renourishment volume	269,000 m^3/year
Fill length	14.5 km
Fill elevation (above msl)	
Beach berm	4.6 m
Storm dune	4.9 m
Beach width increase	15 to 27 m
Average volume loss	13.8 to 20 m^3/m/year
Average recession rate	0.3 to 1.5 m/year
Borrow Site Characteristics	
	Middle Ground Shoal
Site area	2.6 km^2
Average water depth	2 m
Average thickness	6.7 m
Sediment volume	19,300,000 m^3
Distance from project	1-6 km
Additional Considerations	
Initial cost	$14,990,000 (1973)
Annual cost	$635,000 (1973)
Other features	Terminal groin systems at eastern and western ends of project
	Limestone crops out at 2 m beneath bottom in some areas

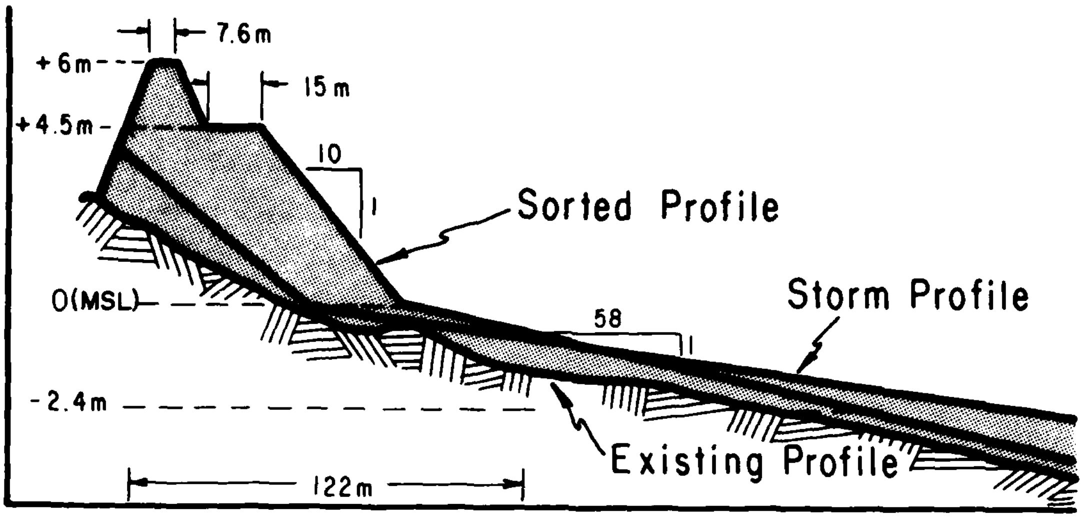

Figure 14. Beach fill section, Brunswick County, N.C.

Table 17

Composite Grain Size Distributions,

Brunswick County, N.C.

Size mm	Size ϕ	Native Beach (130 Samples)	Borrow Area (98 Samples)
1.41	-0.5	0	0.3
1.0	0.0	0.7	3.4
0.71	0.5	3.3	13.5
0.5	1.0	15.1	33.2
0.35	1.5	35.9	53.5
0.25	2.0	55.5	70.0
0.18	2.5	78.8	88.2
0.12	3.0	94.1	97.8
0.07	3.5	99.4	100.0
Phi mean		1.90	1.56
Mean (mm)		0.28	0.34
Phi sorting		0.80	0.98

43. Table 18 summarizes the comparison of native beach sediments with Middle Ground Shoal sands using the adjusted SPM fill factor (R_A) and the renourishment factor (R_J). An adjusted fill factor (R) is also defined in Table 18. This factor is used in the original GDM to adjust for the proportion of clay and silt contained in the shoal sands. These fine sized sediments were judged dynamically unstable in the beach environment and are expected to be lost during, or soon after, dredging and placement.

Table 18

Beach Fill Model Calculations, Brunswick County, N.C.

Fill factor (R_A)	1.00
Adjusted fill factor (R)*	1.12
Renourishment factor (R_J)	0.61

* Adjusted R_A value for borrow area (Middle Ground Shoal) which contained 89 percent of sediment coarser than 4ϕ (sand/silt size boundary) $R = R_A$ (100/89).

Hunting Island, S.C.

44. Hunting Island is located along the southeastern shore of South Carolina in Beaufort County. The island is a state park with an average elevation of 3.7 m above mlw, average width of 1.2 km, and about 6.9 km of ocean frontage consisting of a nearly straight continuous sandy beach (Figure 15). There is no Federally owned shoreline on the island, but severe erosion in the area prompted the South Carolina State Highway Department in 1959 to request that the Corps of Engineers initiate studies to determine the best methods for arresting the erosion and stabilizing the beach. This request was approved by the Chief of Engineers on 8 September 1959, and the survey report was completed in 1963.

45. The general conclusions in the report (U. S. Army Engineer District, Charleston 1963) were that:

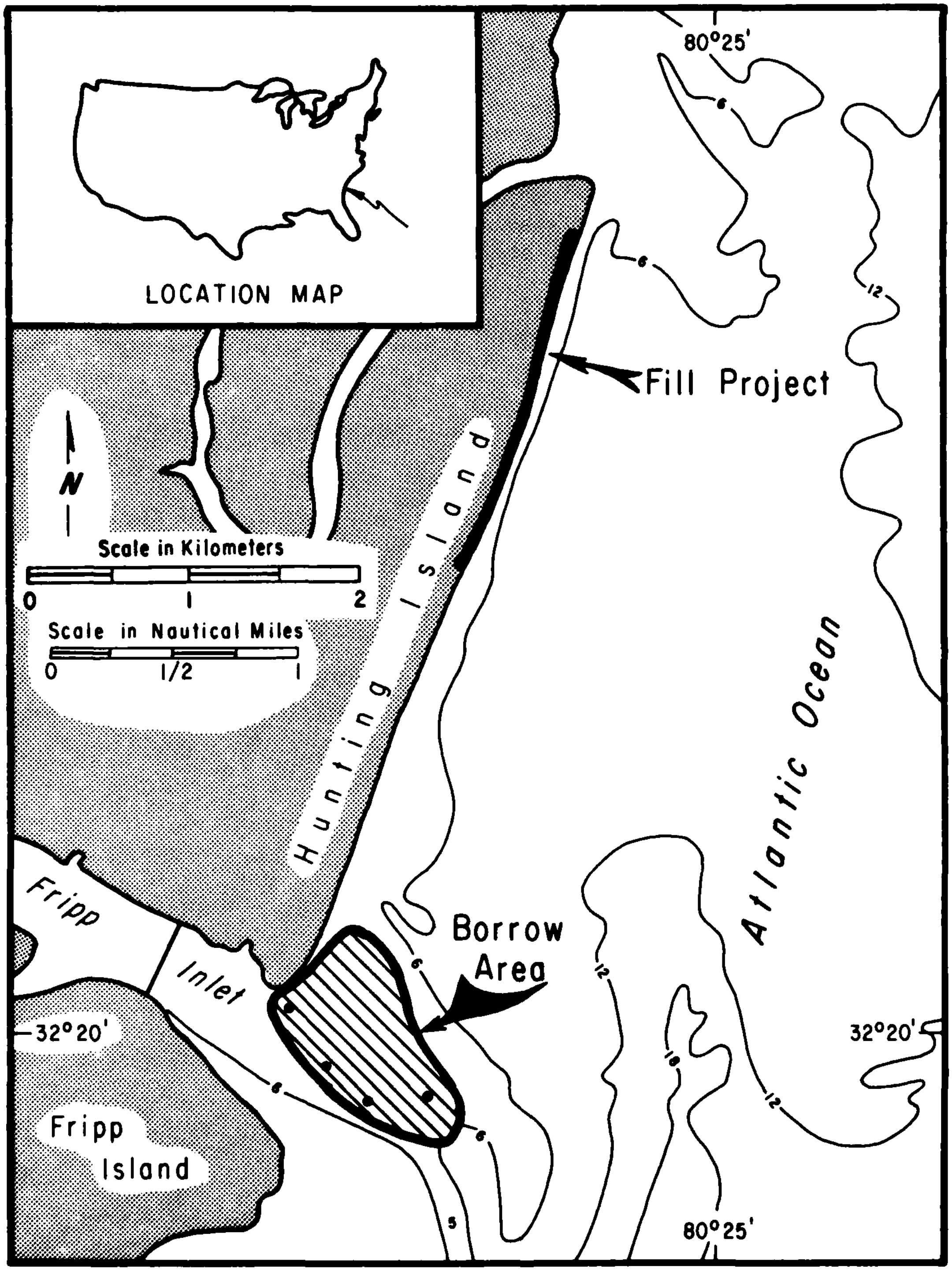

Figure 15. Location and bathymetry, Hunting Island, S.C.
(depth contours in feet)

a. The high-water line along the beachfront had receded between 30 and 150 m since 1948.

b. No significant amount of sediment reaches the area from updrift barrier beaches. Instead, most southerly littoral transport becomes trapped in St. Helena Sound as shoals in the inlet and on the outer bar.

c. No significant sand dunes remain in the area to nourish the beach during storm events.

d. Man-made groins and bulkheads have performed unsatisfactorily to combat erosion. Because of high recession rates, these structures have been flanked and have tended to accelerate downdrift (southerly) erosion.

46. Two protection plans were evaluated (plans A and B). Each included construction of a northern terminal groin and a feeder beach that would contain sufficient volume to supply nourishment requirements for three years (570,000 m^3). Initial construction of the authorized project, plan A (Figure 16, Table 19), was completed in December 1968. Sand for the feeder beach was obtained from a borrow area located along Johnson Creek on the westerly side of Hunting Island. Unfortunately, unusually active storms occurred during 1969 and 1970 that accelerated erosion

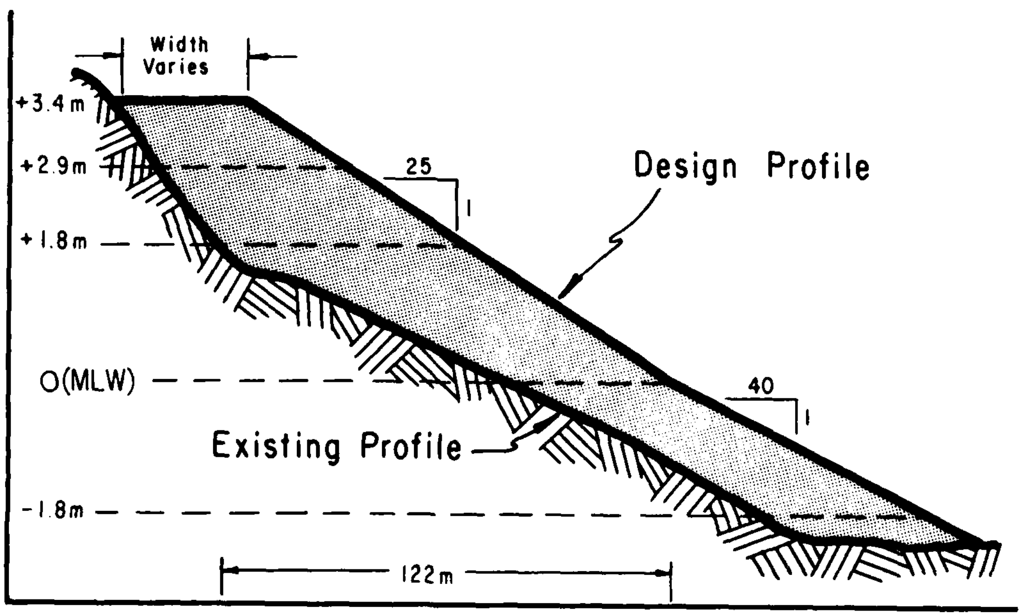

Figure 16. Beach fill section, Hunting Island, S.C.

Table 19

Project Specifications, Hunting Island, S.C.

Beach and Fill Characteristics	
Initial fill volume	570,000 m^3
Renourishment volume	123,000 m^3/year
Fill length	3.1 km
Fill elevation (above mlw)	2.8-m berm
Beach width increase	30-m avg
Average volume loss (long term)	91,200 m^3/year
Average recession rate	4.3 m/year
Maximum recession	7.6 m (1959)
Borrow Site Characteristics	
	Fripp Inlet Shoal
Site area	1.0 km^2
Average water depth	2 m
Average thickness	6.0 m
Sediment volume	6,000,000 m^3
Distance from project	5.5 km
Additional Considerations	
Initial cost	$609,578 (1968)
Annual cost	$97,500
Other project features	Terminal groin
Monitoring planned	Yes
Other	Nourishment in: 1971 (579,000 m^3) 1975 (466,000 m^3)

and produced a need for renourishment two years after project completion. In August 1971 an additional 579,000 m^3 of sediment was pumped to the feeder beach from the Johnson Creek borrow area. A second renourishment of 466,000 m^3 was completed four years later in June 1975. This time the sand was obtained from an ebb tidal shoal complex located at the mouth of Fripp Inlet (Figure 15). The texture of this material is nearly identical to that for native beach sediment (Tables 20 and 21).

Table 20

Composite Grain Size Distributions, Hunting Island, S.C.

Size mm	Size ϕ	Native Beach (21 Samples)	Fripp Inlet Borrow (23 Samples)	Johnson Creek Borrow (2 Samples)
1.0	0.0	0.2	0.3	0.5
0.7	0.50	1.3	0.9	1.5
0.5	1.0	4.2	1.8	5.0
0.35	1.50	6.8	4.0	8.5
0.25	2.0	12.5	9.6	12.5
0.18	2.5	36.5	48.5	31.5
0.13	3.0	86.1	84.0	77.5
0.09	3.5	99.6	97.3	99.5
0.06	4.0	99.9	99.9	100.0
Phi mean		2.53	2.55	2.60
Mean (mm)		0.17	0.17	0.16
Phi sorting		0.43	0.45	0.50

Table 21

Beach Fill Model Calculations, Hunting Island, S.C.

	Fripp Inlet	Johnson Creek
Fill factor (R_A)	1.00	1.10
Renourishment factor (R_J)	1.00	1.00

47. Although short-term volumetric losses have varied, this project has generally performed as designed. The number of years required for the loss of 570,000 m^3 for the 1968, 1971, and 1975 fills are 2.62, 3.11, and 4.24, respectively (U. S. Army Engineer District, Charleston 1977). The sand from Fripp Inlet appears to be a more suitable fill sediment. One shortcoming of the project design is that sand from the feeder beach is not being transported southward as quickly as anticipated.

Tybee Island, Ga.

48. Tybee Island (Figure 17) is located directly south of the Savannah River entrance to the Atlantic Ocean, and is about 27 km east of the city of Savannah, Ga. Tybee Island is about 5.6 km long and has an average width of 1 km. Behind the beach lies a line of sand dunes, many of which have been removed to make room for construction along the shore. The ocean beach was traditionally wide and sandy, but by 1970 erosion to the northern 2.5 km created beach elevations less than the 2.0-m mhw elevation. In this area a seawall located slightly offshore provided the only protection against tides, waves, and flooding. Groins that were built in the 1920's also existed in the area, but they were in bad condition and almost completely ineffective. The beach south of the eroded section was relatively stable and had accreted slightly during the past 25 years (U. S. Army Engineer District, Savannah 1970).

49. The topography of the area is characterized by barrier islands, sand dunes, tidal inlets, and marshes. Sediments found in these geomorphic features are of Recent age and are made up of reworked Pleistocene deposits mixed with materials discharged by the Savannah River. A longshore current from the north supplies most beach sediments. These currents are affected locally by tidal flooding of the Savannah River and Tybee Creek estuary. Rock entrance jetties were built at the mouth of the Savannah River in the 1890's. The specific effects that these structures have upon the Tybee Island erosion problem are unclear (a study is currently under way to determine these effects). Since the jetties extend nearly 3.5 km into the Atlantic, they must function to some degree

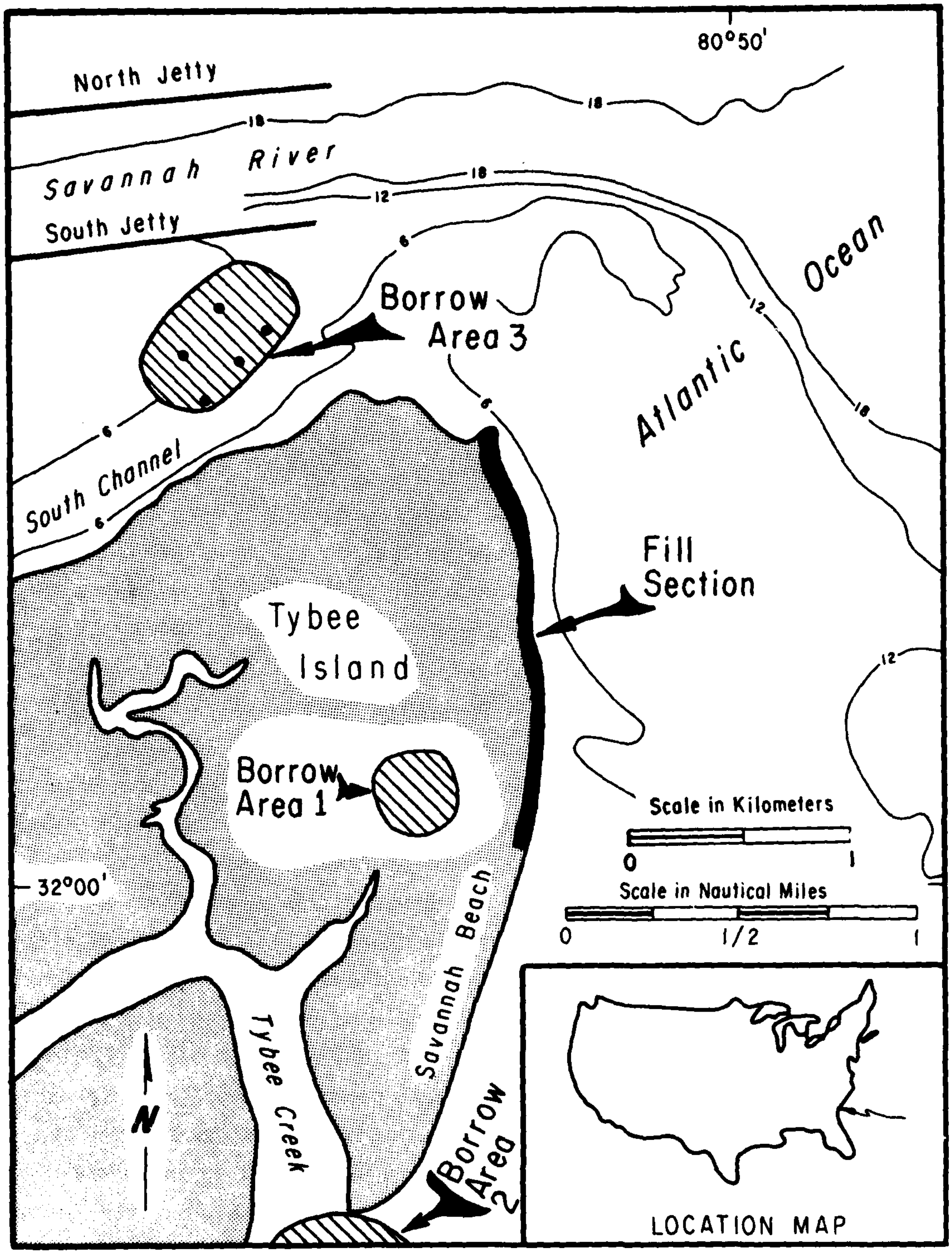

Figure 17. Location and bathymetry, Tybee Island, Ga. (depth contours in feet)

as barriers to littoral drift and may also serve to shadow the northern portion of the island from the natural movement of sediments to the south. The southern 1.6 km of the island had remained stable during the period of 1945 to 1970.

50. The plan of improvement (Figure 18, Table 22) provided by the Corps of Engineers (U. S. Army Engineer District, Savannah 1970) recommended the construction of groins and renourishment of the eroded beach. The groins included a 244-m-long structure at the northern end of the improvement to protect against sand losses to tidal currents and to provide beach alignment, and two 146-m-long structures at locations 460 and 920 m south of the terminal groin to help contain the fill. The initial fill (585,200 m^3) and an additional 231,000 m^3 of sediments were to be placed during reconstruction to provide for anticipated losses during the first three years of the project.

51. Sixteen beach samples were collected and used to determine native composite properties. These samples all had median diameters that were less than 0.40 mm because samples collected with greater median

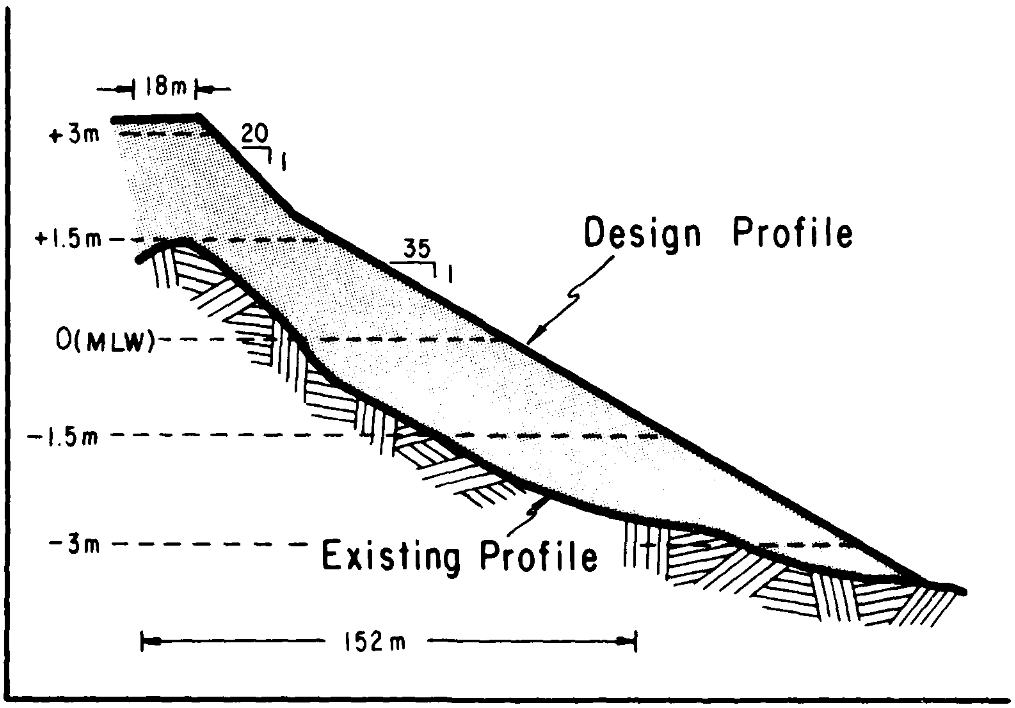

Figure 18. Beach fill section, Tybee Island

Table 22

Project Specifications, Tybee Beach, Ga.

Beach and Fill Characteristics

	Tybee Beach
Initial fill volume	585,200 m^3
Renourishment volume	77,000 m^3/year
Advanced renourishment	231,000 m^3
Fill length	2.5 km
Fill elevation (above mlw)	
Beach berm	3.3 m
Beach width increase	18 m at berm
Average volume loss	173,200 m^3/year

Borrow Site Characteristics

	Borrow Area 3 Tybee Knoll Spit	Borrow Area 2 Tybee Creek Inlet	Borrow Area 1 Horse Pen Creek
Site area	0.73 km^2	0.80 km^2	0.35 km
Average water depth	1.6 m	1.0 m	0.1 m
Average thickness	5.2 m (under 1.7-m overburden)	2.0 m (estimated)	3.0 m
Sediment volume	3,800,000 m^3	1,620,000 m^3	1,000,000 m^3
Distance from project	2.4 km	2.0 km	0.5 km

Additional Considerations

Initial cost	$985,000 (1970)
Annual cost	$110,000 (1970)
Other project features	1. 243-m terminal groin 2. Two 146-m intermediate groins

diameters were not considered representative of true beach conditions. Three local potential borrow sources were also investigated (Figure 17). Their composite textural properties appear with the native beach composite in Table 23. After comparison of textural properties and evaluation of specific borrow site conditions, it was recommended that the Tybee Creek Inlet area (Borrow Area 2) be utilized for the project. This area contained clean sands with textures nearly identical to the native beach sand. Calculations presented in Table 24 indicate that Tybee Knoll Spit sediments (Borrow Area 3) would probably outperform Tybee Creek sediments as fill, but the spit area is exposed to strong wave and current action and is overlain by 1.7 m of sediment that would be unsuitable as fill.

52. The authorized project began in June 1975 and was completed by March 1976. The project was expanded to include 4 km of shoreline. Nourishment began at the southern tip of the area using fill sediments from the Tybee Creek entrance shoal and progressed northward until completion. Approximately 1,719,000 m^3 of sand were placed in this manner. Losses have been 2 to 3 times greater than anticipated. At this writing, approximately 11.5 percent has been lost from the entire project and greater than 65 percent has been eroded from the southernmost kilometre of the island.

Nassau County, Fla.

53. The Atlantic shoreline of Nassau County, Fla., is located along Amelia Island, which is a 21-km-long barrier island situated between the mouths of the St. Mary's River to the north and Nassau River to the south. Fernandina Beach is the largest city on the island and is located at the north end (Figure 19). Significant erosion has occurred along approximately 6 km of the Fernandina Beach shoreline and 0.6 km of the Fort Clinch State Park shoreline, which is adjacent to the St. Mary's River on the north end of the island. The severity of erosion prompted Federal funding in 1974 for a beach erosion control study for the entire island with results published in review form by the

Table 23

Composite Grain Size Distributions, Tybee Island, Ga.

Size mm	Size φ	Native Beach	Horse Pen Creek (3 Cores)	Tybee Creek Inlet (13 Cores)	Tybee Knoll Spit (5 Cores)
2.0	-1.00	0.0	0.0	0.0	10.0
1.41	-0.50	0.0	0.0	0.0	14.0
1.00	0.0	0.0	0.0	0.0	17.0
0.71	0.50	0.0	0.0	0.0	25.0
0.50	1.00	2.0	0.0	1.0	35.0
0.35	1.50	4.0	1.0	3.0	48.0
0.25	2.00	30.0	14.0	21.0	67.0
0.18	2.5	55.0	45.0	50.0	74.0
0.12	3.0	85.0	86.0	85.0	84.0
0.07	3.5	98.0	99.0	95.0	95.0
Phi mean		2.38	2.50	2.44	1.40
Mean (mm)		0.19	0.18	0.18	0.38
Phi sorting		0.58	0.45	0.51	1.60

Table 24

Beach Fill Model Calculations, Tybee Island, Ga.

	Horse Pen Creek	Tybee Creek Inlet	Tybee Knoll Spit
Fill factor (R_A)	1.60	1.15	1.15
Renourishment factor (R_J)	1.40	1.20	0.14

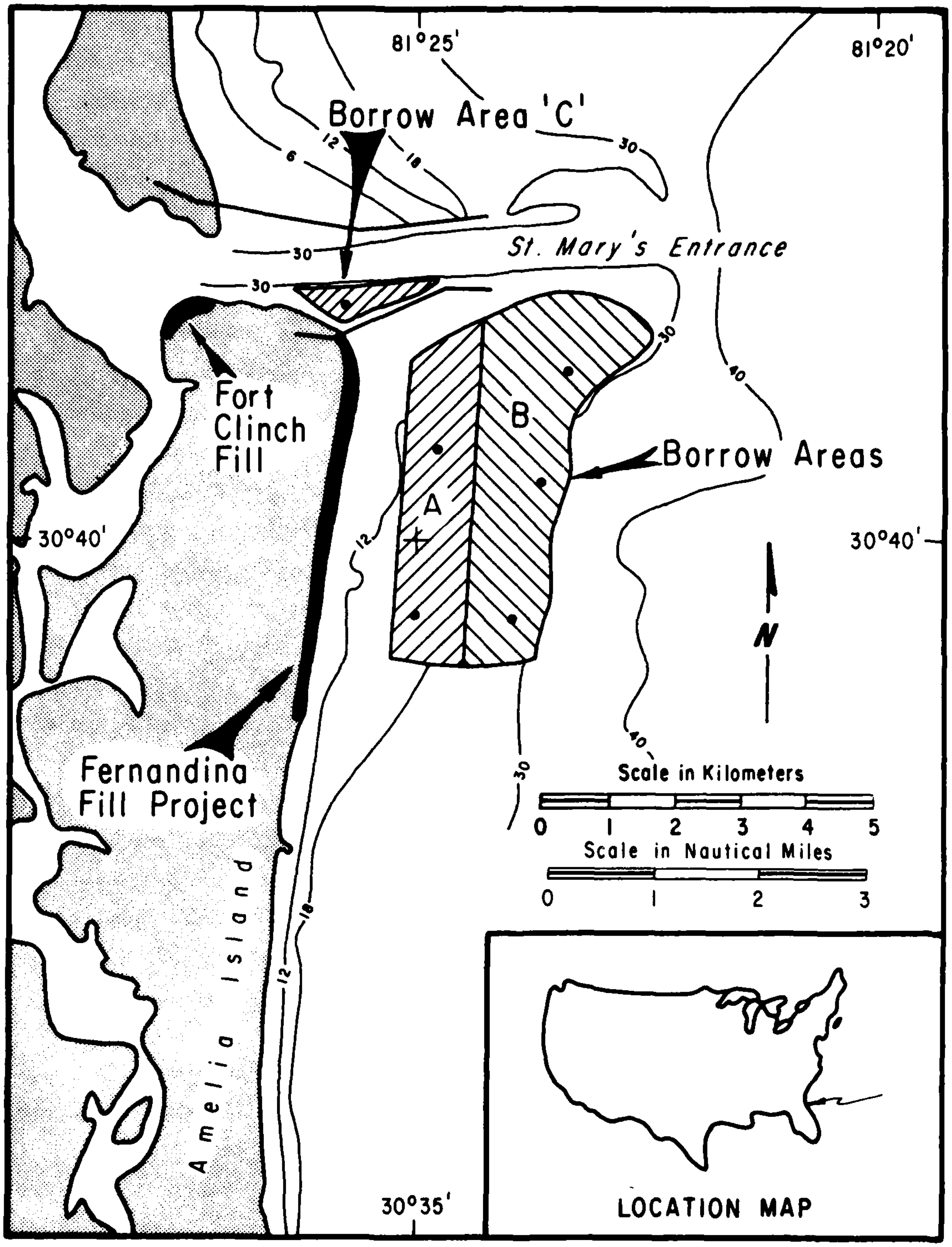

Figure 19. Location and bathymetry, Nassau County, Fla.
(depth contours in feet)

Jacksonville District (U. S. Army Engineer District, Jacksonville 1977c). The report concludes that the erosion problems investigated were caused by normal shore processes, storm waves and surges, and existing structures in the area. The following discussion, graphics, and tables were obtained from the review report and from the files of the Jacksonville District.

54. A previous report relative to beach erosion in the area was completed by the U.S. Army Engineer District, Savannah (1960). This study states that the Amelia Island erosion problems are primarily due to starvation of the beach caused by the interruption of littoral transport by two navigation jetties. These jetties were built during the period 1881-1903 at the St. Mary's River entrance to provide a 10-m-deep access channel into Fernandina Harbor. The north jetty drastically reduces the southerly transport of sand across the inlet during the winter season, while much of the northerly transported sand during the summer passes through the porous south jetty and is deposited in the inlet. The jetties not only create a littoral barrier but also cause the redistribution of sand carried northward, resulting in the realignment of the shoreline from north-south to a more easterly direction. Starvation and redistribution of sediments has resulted in an average annual loss of 250,000 m^3 of sand from an area extending from 1.2 to 7.6 km south of the entrance jetty. Erosion losses in the Fort Clinch area are about 8,000 m^3/year and are attributed to the deterioration of groins that had historically protected the area from erosion from strong ebb tidal currents. A third area of erosion, for which no immediate remedies were recommended, occurs on the sparsely populated southern end of Amelia Island.

55. The plan recommended to combat the erosion problems (Table 25, Figure 20) calls for beach fill to restore the critically eroded reaches at Fernandina Beach and Fort Clinch, refurbishing the groins at Fort Clinch, sealing the south entrance jetty of Fernandina Harbor to prevent further losses of longshore drift through the structure, and construction of a 150-m-long groin approximately 2.4 km south of the harbor entrance.

56. Six offshore borrow areas were investigated in 1960 as

Table 25

Project Specifications, Nassau County, Fla.

Beach and Fill Characteristics

	Fernandina Beach	Fort Clinch State Park
Initial fill volume	985,600 m^3	53,900 m^3
Renourishment volume	154,000 m^3/year	7,700 m^3/year
Fill length	6.1 km	1.5 km
Fill elevation (above mlw)	4.0 m	3.0 m
Beach width increase	6 m	6 m
Average volume loss	15,000-23,000 m^3/year	8,000 m^3/year
Average recession rate	0.2 m/year	Unavailable

Borrow Site Characteristics

	Borrow A	Borrow B	Borrow C
Site area	4.7 km^2	8.8 km^2	0.7 km^2
Average water depth	4.4 m	5.7 m	5.2 m
Average thickness	7.3 m	5.8 m	3.0 m
Sediment volume	34,310,000 m^3	52,000,000 m^3	2,000,000 m^3
Distance from project	3.0 km	4.0 km	5.0 km

Additional Considerations

	Fernandina Beach	Fort Clinch State Park
Initial cost	\$5,780,000	\$870,000
Annual cost	\$138,500	\$43,000
Other project features	1. Central groin at Fernandina 2. Make south jetty less porous	Reconstruct 5 groins

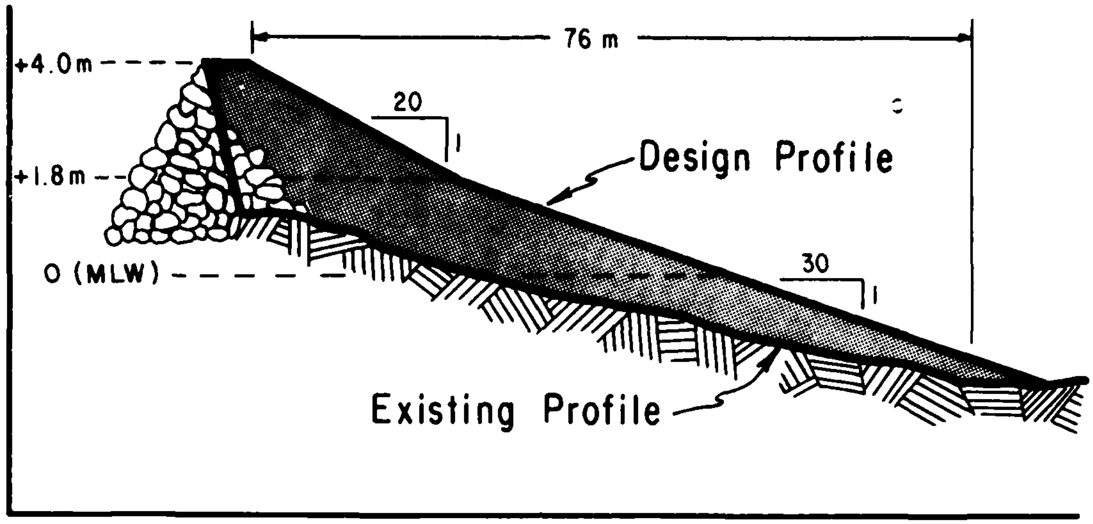

Figure 20. Beach fill section, Nassau County, Fla.

potential beach fill sources. Bottom topography seemed to be the dominant factor controlling the thickness of potential fill sediments at each location in this area. Generally, suitable sands were found in depths shallower than -10 m. Sands in the -10 to -12 m elevation range tended to contain increasing amounts of unsuitable clay and silty lenses, and sands cored to depths greater than -12 m generally contain too much fine material to be suitable. The three potential borrow areas in the shallower water depths, with adequate deposit thicknesses, are shown in Figure 19. The composite gsd's of sediments cored from these areas appear in Table 26 along with composites for the Fernandina and Fort Clinch beaches. Beach and potential borrow areas are compared in Table 27.

Indian River County, Fla.

57. In 1965, the Jacksonville District was assigned to investigate coastal erosion along the 36-km shoreline of Indian River County, Fla. This was the first Federal investigation of beach erosion in the area, although in 1965 the University of Florida Coastal and Oceanographic Laboratory performed model studies for navigation improvements at Sebastian

Table 26

Composite Grain Size Distributions, Nassau County, Fla.

Size mm	Size ϕ	Fernandina Beach (28 Samples)	Fort Clinch State Park (8 Samples)	Borrow A (10 Samples)	Borrow B (11 Samples)	Borrow C (1 Sample)
19.02	-4.25	0.0	0.0	0.0	0.0	0.0
13.45	-3.75	0.1	0.0	0.2	0.0	0.0
9.51	-3.25	0.9	0.1	0.7	0.4	0.0
4.75	-2.25	4.4	0.4	3.1	2.0	0.0
2.00	-1.00	10.1	1.0	6.5	6.2	0.0
0.84	0.25	14.3	2.9	15.7	14.4	1.0
0.42	1.25	22.3	6.5	27.6	23.1	14.0
0.25	2.00	41.6	21.0	39.8	30.9	25.0
0.15	2.75	89.0	82.9	56.9	49.9	84.0
0.07	3.75	100.0	99.4	89.3	85.2	99.4
Phi mean		1.58	2.33	1.89	1.93	2.28
Mean (mm)		0.33	0.20	0.27	0.26	0.21
Phi sorting		1.08	1.48	1.64	1.48	0.88

Table 27

Beach Fill Model Calculations, Nassau County, Fla.

Fernandina Beach

	Borrow A	Borrow B
Fill factor (R_A)	1.22	1.22
Renourishment factor (R_J)	0.59	0.47

Fort Clinch State Park

	Borrow A	Borrow B	Borrow C
Fill factor (R_A)	1.35	1.31	1.25
Renourishment factor (R_J)	0.001	0.006	0.3

Inlet. Recommended measures in the Federal investigation (U. S. Army Engineer District, Jacksonville 1977b) consisted of improvements in the form of beach nourishment and groin structures along the county's northern 2.7 km of shoreline at the Sebastian Inlet State Recreation Area (Figure 21) and along 2.8 km of shoreline extending north from the Riomar Reef at Vero Beach (Figure 22).

58. The study area is located on a barrier island that varies in width from about 50 m opposite the city of Sebastian to nearly 2.1 km about 3 km south of that point. In general, the shoreline outside of the heavily developed 5-km-long urban area at Vero Beach consists of natural beaches backed by highly vegetated dunes. The shoreline is rather straight, but offshore "sabellariid" reefs, which grow to about mlw depth and often affect beach alignment, are common. For example, Riomar Reef off Vero Beach is believed to be the cause of indention of the coast south of the fill project area shown in Figure 22.

59. Both onshore-offshore and alongshore components of sediment transport in the study area are seasonal. Offshore and southerly alongshore movements occur during winter due to the predominance of high-energy storm waves propagating from the northeast. Reversed movement directions occur during the summer, but the prevalence of higher energy winter conditions results in a net annual southerly drift of 22,000 m^3 at Sebastian Inlet and 64,000 m^3 at Vero Beach. Also, during the survey period between 1930 and 1975, the beach north of Sebastian Inlet advanced seaward about 0.5 m/year while the first 4 km of beach to the south receded an average of 0.7 m/year. Beach recession between Sebastian Inlet and Vero Beach has averaged 0.4 m/year, whereas an advance of 1 m/year characterizes beaches to the south of Vero between 1930 and 1975. As a result of these rates of shoreline change, only those two beaches located directly south of Sebastian Inlet and opposite the urbanized Vero Beach area are experiencing sufficient storm damage and erosion to warrant reconstruction.

60. Erosion control measures were recommended by the Jacksonville District, but providing for a system of protection against tidal flooding during hurricanes was considered unrealistic and economically

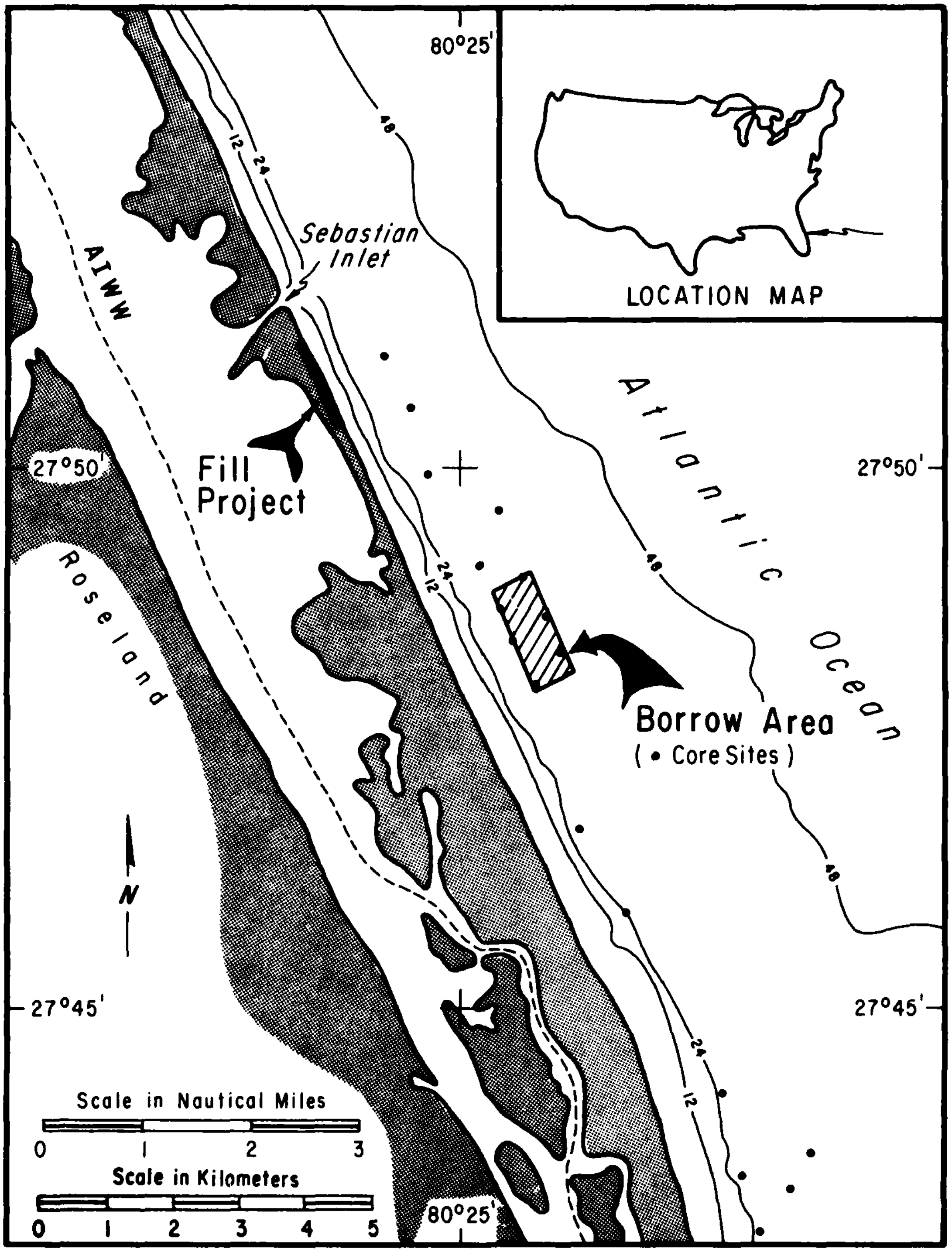

Figure 21. Location and bathymetry, Sebastian Inlet State Recreation Park, Fla. (depth contours in feet)

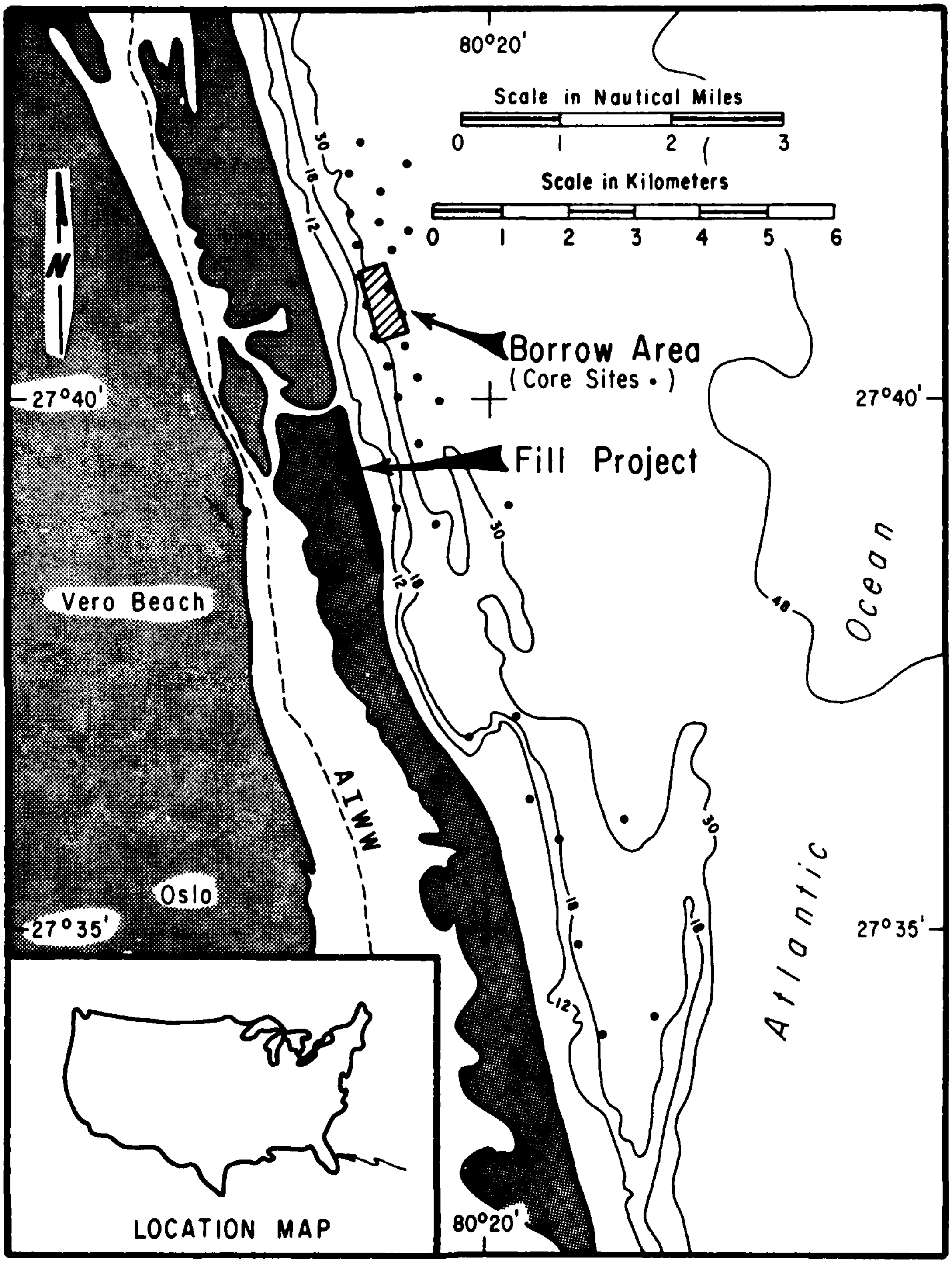

Figure 22. Location and bathymetry, Vero Beach, Fla.
(depth contours in feet)

unjustifiable. The plan (Table 28) recommended for the Indian River County is to fill 2.7 km of the beach at the Sebastian Inlet State Recreation area (Figure 23), beginning 0.5 km south of the jetties, with enough sand to provide for 5 years of advance nourishment (262,000 m^3) and to place 481,000 m^3 on Vero Beach (Figure 24) along 2.8 km north of where Riomar Reef intersects the shore. Groin structures were also recommended in the BEC plan for each fill area to help stabilize the beaches, but deferred construction was recommended.

61. Offshore borrow source areas were evaluated for each fill section. Twenty-eight exploratory borings were drilled along the Indian River County coast in 1973. These borings were located from 0.9 to 1.2 km offshore and spaced about 2 km apart. Textural analyses of sediment from these exploratory cores were used to isolate two potential borrow areas for the anticipated projects (Figures 21 and 22) that were investigated further in 1974 by obtaining 27 more vibratory core samples. Native beach samples were collected along 11 profile lines in 1974, and their composite gsd along with composites for the borrow areas appear as Table 29. Textural comparisons of these sediment sources (Table 30) suggest the proposed borrow areas to be excellent sources of material for beach nourishment.

Dade County, Fla.

62. The Dade County beach fill project is the largest active undertaking of this kind in the United States, with more than 10,000,000 m^3 of sand being placed along nearly 17 km of shoreline (Figure 25). By July 1974, a portion of the Dade project had been completed by local interests at Bal Harbor, which contains 1.5 km of beach south of Bakers Haulover Inlet. As of November 1977, the project was 53 percent complete (1,318,300 m^3) along fill section 1 (Figure 25). The remainder of that section was scheduled for completion in 1978 while completion of section 2 is anticipated by 1982.

63. This is a combined BEC/HUR project (Table 31, Figure 26) designed to protect the greater Miami Beach area, which is probably the

Table 28

Project Specifications, Indian River County, Fla.

Beach and Fill Characteristics

	Vero Beach	Sebastian Inlet Beach
Initial fill volume	481,100 m^3	261,800 m^3
Renourishment volume	22,330 m^3/year	33,418 m^3/year
Fill length	2.8 km	2.7 km
Fill elevation (above mlw)	4.6 m	3.0 m
Beach width increase	12.2 m at mhw	12.2 m at mhw
Average volume loss	29,300 m^3/year	64,700 m^3/year
Average recession rate	0.2 m/year	0.4-0.9 m/year
Maximum recession	23-55 m/hurricane	23-55 m/hurricane

Borrow Site Characteristics

	Vero Site	Sebastian Site
Site area	0.6 km^2	0.8 km^2
Average water depth	8.9 m	11.4 m
Average thickness	3.0 m	6.0 m
Sediment volume	1,800,000 m^3	5,100,000 m^3
Distance from project	3.0 km	3.5 km

Additional Considerations

	Vero Project	Sebastian Project
Initial cost	$2,703,000	$1,624,000 (1975)
Annual cost	$126,500	$164,500 (1975)
Other project features	1 groin, possible offshore breakwater	1 groin
Monitoring planned	Yes	Yes

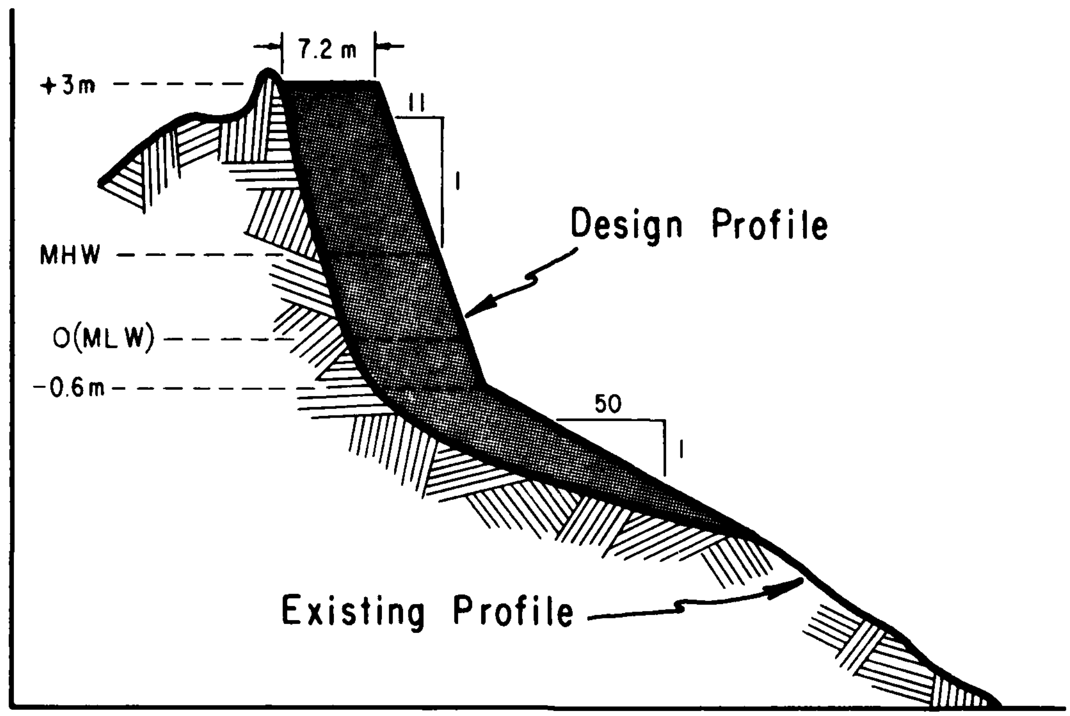

Figure 23. Beach fill section, Sebastian State Recreation Park, Fla.

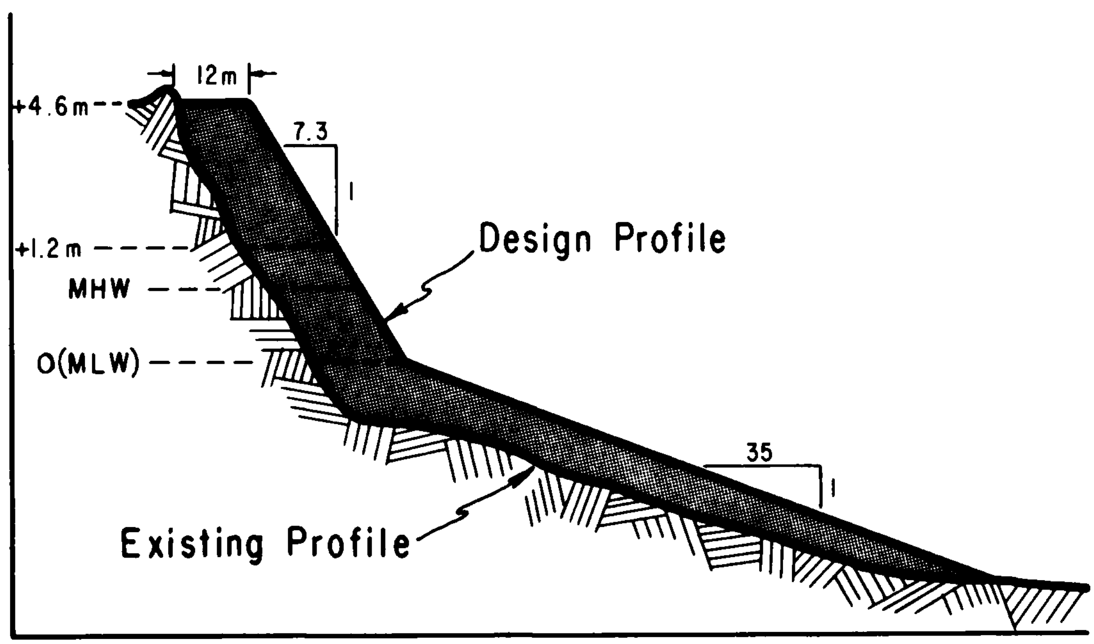

Figure 24. Beach fill section, Vero Beach, Fla.

Table 29

Composite Grain Size Distributions, Indian River County, Fla.

Size mm	Size φ	Native Beach: Vero Beach (15 Samples)	Native Beach: Sebastian Inlet Beach (16 Samples)	Borrow Areas: Vero (18 Samples)	Borrow Areas: Sebastian (12 Samples)
19.02	-4.25	0.6	0.1	2.6	1.2
13.45	-3.75	0.8	0.2	5.4	2.7
9.51	-3.25	0.9	0.5	8.3	5.4
4.75	-2.25	2.5	1.1	16.6	11.3
2.00	-1.00	12.4	4.1	32.4	27.9
0.84	0.25	34.7	16.4	50.2	46.5
0.42	1.25	48.1	34.6	64.7	58.8
0.25	2.00	70.3	70.2	74.3	77.9
0.15	2.75	84.3	91.3	78.7	88.2
0.07	3.75	94.9	97.9	88.4	94.6
Phi mean		1.00	1.30	0.48	0.29
Mean (mm)		0.50	0.41	0.72	0.82
Phi sorting		1.73	1.09	2.70	2.09

Table 30

Beach Fill Model Calculations, Indian River County, Fla.

	Vero Beach	Sebastian Inlet Beach
Fill factor (R_A)	1.03	1.03
Renourishment factor (R_J)	0.36	0.11

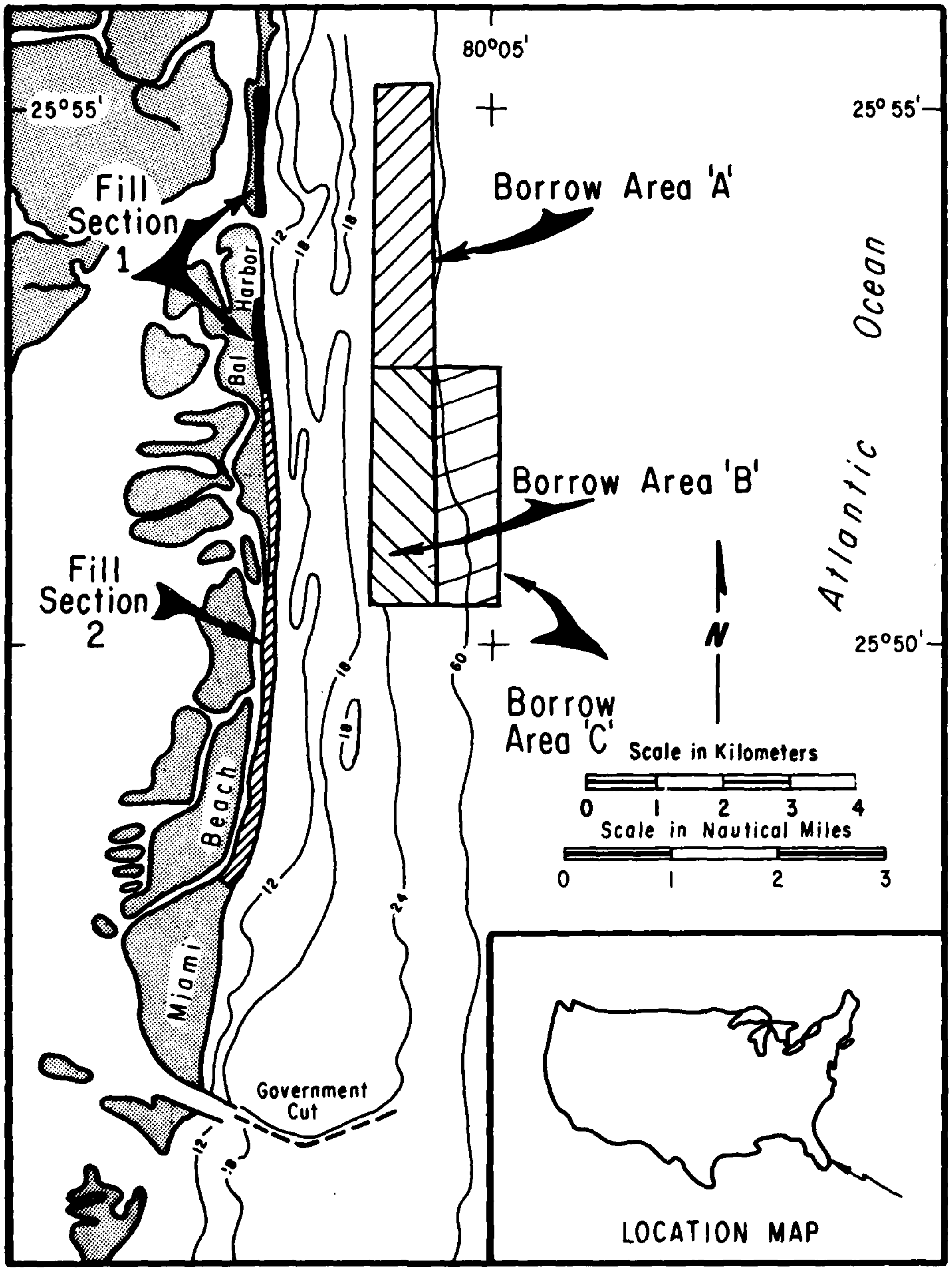

Figure 25. Location and bathymetry, Dade County, Fla. (depth contours in feet)

Table 31

Project Specifications, Dade County, Fla.

Beach and Fill Characteristics

	Dade County
Initial fill volume	10,395,000 m^3
Renourishment volume	162,470 m^3/year
Advanced renourishment	324,940 m^3
Fill length	16.9 km
Fill elevation (above mlw)	
Beach berm	2.7 m
Storm berm	3.5 m
Hurricane dune	15.2 m
Beach width increase	6.0-m berm
Average volume loss	122,000 m^3/year (minimum)

Borrow Site Characteristics

	Borrow A	Borrow B	Borrow C
Site area	3.1 km^2	2.3 km^2	1.6 km^2
Average water depth	14.8 m	13.7 m	17.8 m
Average thickness	4.5 m	4.3 m	5.0 m
Sediment volume	14,000,000 m^3	10,000,000 m^3	8,000,000 m^3
Distance from project	2.0-13.0 km	1.6-6.0 km	2.0-7.0 km

Additional Considerations

Initial cost	$45,322,000 (1975)
Annual cost	$2,776,000 (1975)
Monitoring planned	2-year plan and $175,000 authorized
Other	Inactive reef structures which could damage dredge
	Plants occupy the margins of the sand deposits

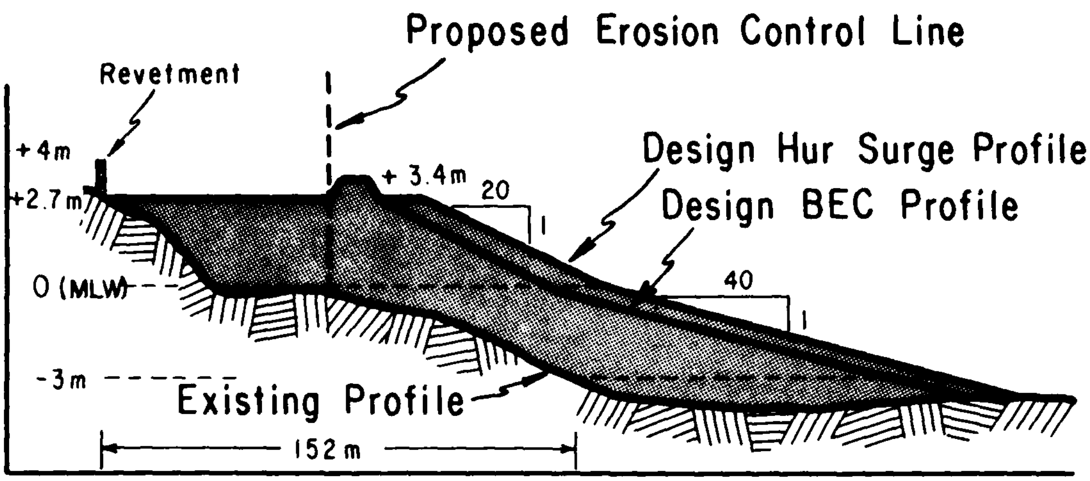

Figure 26. Beach fill section, Dade County, Fla.

most highly developed and densely concentrated luxury class resort area in the world (U. S. Army Engineer District, Jacksonville 1965). Prior corrective action for the area included nearly 100 groins built mainly around 1927 to 1930, over 12 km of seawalls, and placement of approximately 220,000 m^3 of fill sediment on beaches on either side of Bakers Haulover Inlet in the early 1960's. Additional structures in the area include entrance jetties at Bakers Haulover Inlet and Government Cut. The parallel jetties at Government Cut are 300 m apart and exceed 800 m in length, whereas the southern Haulover jetty extends about 200 m into the Atlantic Ocean.

64. Beach erosion has caused loss of valuable property and in a number of locations has undermined or threatened to undermine shorefront structures. Average annual erosion rates are estimated to be at least 122,000 m^3. Recession rates are difficult to document since a general practice in the area has been to install seawalls at the mhw level, leaving only a low tide beach. Nevertheless, erosion is mainly attributed to the effects of northeast storms and hurricanes (U. S. Army Engineer District, Jacksonville 1975). Waves and currents generated by northeast storms cause more erosion to the beaches in 2 or 3 months than results from other activities during the remainder of the year. Hurricanes and severe tropical storms occur about every 3 years and usually cause

extensive flooding, as well as erosion. During the hurricane of 1926, flooding reached depths up to 1 m on the island and left water ponded to elevation +4 m mlw near the ocean. Since 1925, it is estimated that Miami Beach has been subjected to $70 million of damage from hurricanes.

65. Studies have been undertaken to isolate beach erosion effects caused by entrance jetties at the north and south limits of the project area. A study completed in 1971 by the Jacksonville District recognized potential erosion problems to the south of Bakers Haulover Inlet, but shoaling rates in the inlet are estimated at only 6,000 m^3 annually because other structures updrift from Bakers Haulover tend to trap sediments before they reach the inlet. Only 5,300 m^3 of sediment are estimated to be trapped yearly in the navigation channel at Government Cut. Changes in offshore topography and wave-energy flux calculations were used to estimate net southerly longshore transport rates of 165,000 m^3/year and 179,000 m^3/year, respectively. The conclusion drawn from these shoaling and longshore transport rates is that creation of the two inlets has isolated the area from natural nourishment and has created a physiographic unit that loses material naturally, but can only gain material by artificial means, such as beach fills.

66. Extensive investigations have been conducted to develop offshore borrow source areas. The region offshore is characterized by a series of parallel fossil reefs with trenches in between that contain unconsolidated sediments composed of quartz sand and shell material. Composite gsd's for sediment cored from three of these trench sections and gsd's of the two sections of the fill project are included as Table 32. Table 33 contains beach fill model calculations. In general, Borrow Area A (Figure 25) contains an adequate supply of suitable fill materials to satisfy project requirements. Borrow Areas B and C are also evaluated because they lie closer to fill section 2. Additional exploration within these larger offshore areas has been undertaken by the Jacksonville District to isolate specific borrow sites.

Key West, Fla.

67. The southern shore of Key West is publicly owned and is

Table 32

Composite Grain Size Distributions, Dade County, Fla.

Size		Native Beach		Borrow		
mm	ϕ	Section 1 (26 Samples)	Section 2 (24 Samples)	Borrow A (26 Cores)	Borrow B (36 Cores)	Borrow C (8 Cores)
4.75	-2.25	3.0	1.3	5.6	5.3	4.9
2.00	-1.00	7.6	2.8	10.1	9.1	8.1
0.84	0.25	27.4	14.1	24.9	27.5	18.1
0.42	1.25	63.3	45.7	41.4	41.5	28.0
0.25	2.00	87.0	79.8	60.9	62.3	41.5
0.15	2.75	96.3	94.5	80.4	80.8	52.1
0.07	3.75	99.7	99.9	91.3	94.6	81.8
Phi mean		0.80	1.28	1.28	1.53	1.98*
Mean (mm)		0.57	0.41	0.41	0.35	0.25*
Phi sorting		1.15	0.93	1.73	1.43	1.88*

* ϕ84 estimated by graphical extrapolation.

Table 33

Beach Fill Model Calculations, Dade County, Fla.

Native Beach	Borrow A	Borrow B	Borrow C
Section 1			
Fill factor (R_A)	1.38	3.98	3.00
Renourishment factor (R_J)	0.70	2.73	2.10
Section 2			
Fill factor (R_A)	1.30	1.35	1.75
Renourishment factor (R_J)	0.28	0.58	0.39

approximately 6.4 km in length. The Jacksonville District issued a BEC report (U. S. Army Engineer District, Jacksonville 1957) in which they summarized the findings from a study of the area made in cooperation with the city of Key West. The purpose of the study was to determine the best method for restoring and maintaining a protective and recreational beach along a 1.9-km section (Figure 27) of the study area.

68. The study beach is of calcareous sandy sediment and is exposed to waves from the Straits of Florida. The interaction of deepwater waves with a barrier reef lying about 8 km offshore tends to reduce their energy considerably and to produce westward longshore currents. However, due to a lack of sand deposits on the shallow, rocky bottom that characterizes the area, no rates of longshore transport can be determined. The rocky bottom extends for at least 1.2 km offshore (7.3-m water depth), and thus seasonal fluctuations along the offshore portions of beach profiles are rare. Nevertheless, annual losses of about 15,400 m^3 were estimated from the area extending to the -10 m contour.

69. The somewhat novel nourishment plan proposed called for excavation of a 2-m-deep trench (Figure 28, Table 34) offshore at the existing -0.6 m mlw elevation and for placing the rocky material excavated (63,910 m^3) above mlw to serve as a core for the beach to be constructed. Fill sediments (104,720 m^3) would then be placed over the rocky surfaces of both the core and trench. The trench was also designed to serve as a trap for sediments transported offshore and alongshore in the area. Sediments for periodic renourishment of the beach were to be obtained from the trench (7,700 m^3/year) and from an outside source (7,700 m^3/year).

70. The Northwest Channel area (Figure 27) was chosen as the best source area for fill sediments among the several areas investigated. The sediment is composed primarily of calcareous sands with an average silt plus clay content of about 20 percent by weight. Dredge-loaded barges were to be used to deliver fill sediments to the project area. The gsd's of 14 probe samples from the Northwest Channel area were used for the borrow sediment composite gsd (Table 35). The [illegible]ve beach composite is the averaged gsd's of samples collected along seven profile lines in the study area. The beach fill model calculations are shown in Table 36.

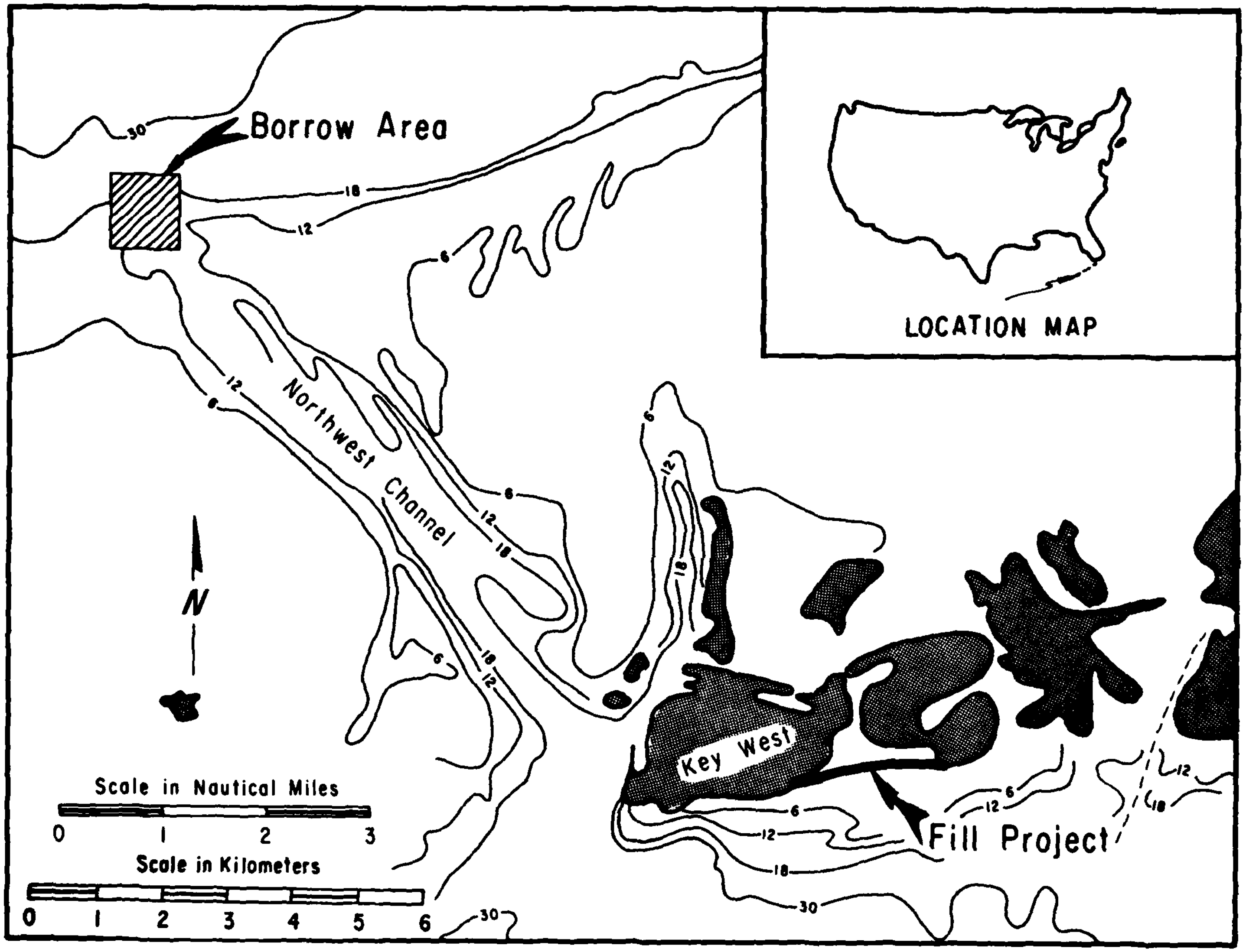

Figure 27. Location and bathymetry, Key West, Fla. (depth contours in feet)

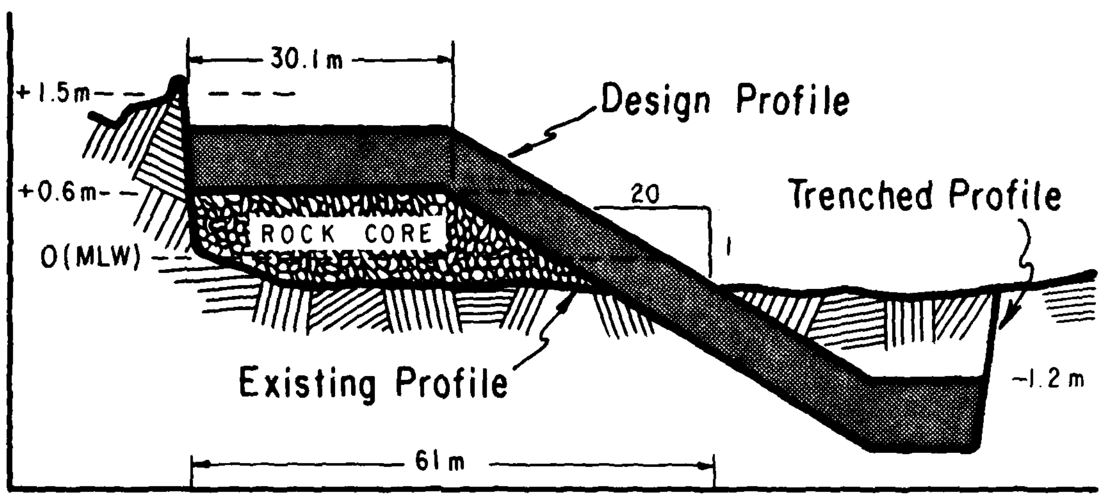

Figure 28. Beach fill section, Key West, Fla.

Table 34

Project Specifications, Key West, Fla.

Beach and Fill Characteristics	
	Key West
Initial fill volume	104,720 m^3
Rock core volume	63,910 m^3
Renourishment volume	15,400 m^3/year
Fill length	1.9 km
Fill elevation (above mlw)	3.0 m
Beach width increase	30.5 m
Average volume loss	15,400 m^3/year
Borrow Site Characteristics	
	Northwest Channel Area
Site area	1.2 km^2
Average water depth	4.6 m
Average thickness	5.7 m
Sediment volume	6,840,000 m^3
Distance from project	27 km
Additional Considerations	
Initial cost	$693,600 (1957)
Annual cost	$76,360 (1957)
Monitored	Yes
Other	Beach fill laid over rock core dredged at -0.6-m elevation offshore

Table 35

Composite Grain Size Distributions, Key West, Fla.

Size mm	Size ϕ	Native Beach (7 Samples)	Northwest Channel (14 Samples)
9.51	-3.25	0.0	0.0
4.75	-2.25	4.3	0.1
2.00	-1.00	10.4	12.5
0.84	0.25	19.3	32.0
0.42	1.25	31.4	61.2
0.25	2.00	42.9	84.9
0.18	2.50	56.2	88.5
0.15	2.75	65.8	93.7
0.07	3.75	84.6	95.7
Phi mean		1.78	0.87
Mean (mm)		0.29	0.54
Phi *sorting*		1.93	1.12

Table 36

Beach Fill Model Calculations, Key West, Fla.

Key West Beach/Northwest Channel Borrow Source	
Fill factor (R_A)	1.01
Adjusted fill factor (R*)	1.26
Renourishment factor (R_J)	0.87

* Adjusted R_A value for Northwest Channel sediments which contained an average of 79.9 percent of sediment coarser than 4ϕ (sand/silt size boundary). $R = R_A \left(\frac{100}{79.9}\right)$

71. The actual project was not completed as designed in 1957. The western 1.0 km was filled in the period April 1959 to March 1960. The offshore trench was excavated to a greater depth than initially proposed in the plan. Part of the rock excavated was placed on the beach as core material and the remainder was crushed and placed over the core and trench as a 0.2-m-thick fill blanket, which itself was overlain by an additional 0.1 m of builder's sand trucked to the area. Four groins were also constructed along the filled reach. The eastern 0.9-km portion has not been restored.

Charlotte County, Fla.

72. Charlotte County is located on the Gulf shore of central Florida (Figure 29). Shore erosion and storm damage have affected the area over the past years to the extent that in 1972 the Chief of Engineers assigned the Jacksonville District the task of studying the county shoreline and preparing a feasibility report for establishing BEC measures (Table 37, Figure 30). This report was released in draft form (U. S. Army Engineer District, Jacksonville 1977a) and serves as the major source for the following maps and tables. The textural data contained herein were obtained from District files because they appear only in abbreviated form in the feasibility report.

73. The study objectives were both general and specific. The general objectives were to establish flexible guidelines for erosion control that would maintain the environmental integrity of the area, its wildlife and waters, and that would be responsive to public needs and consensus. The specific objectives of the study were to protect critically eroded public beaches, provide a nourishment program to compensate for future erosion losses, and determine Federal and non-Federal cost sharing arrangements for the recommended plan(s) of action. The area selected for improvement constitutes the northernmost 6.3 km of Charlotte County's 22.5-km-long coastline. The southern two thirds of the county shoreline is privately owned and generally inaccessible except by boat.

74. There are no known previous Federal BEC investigations in the

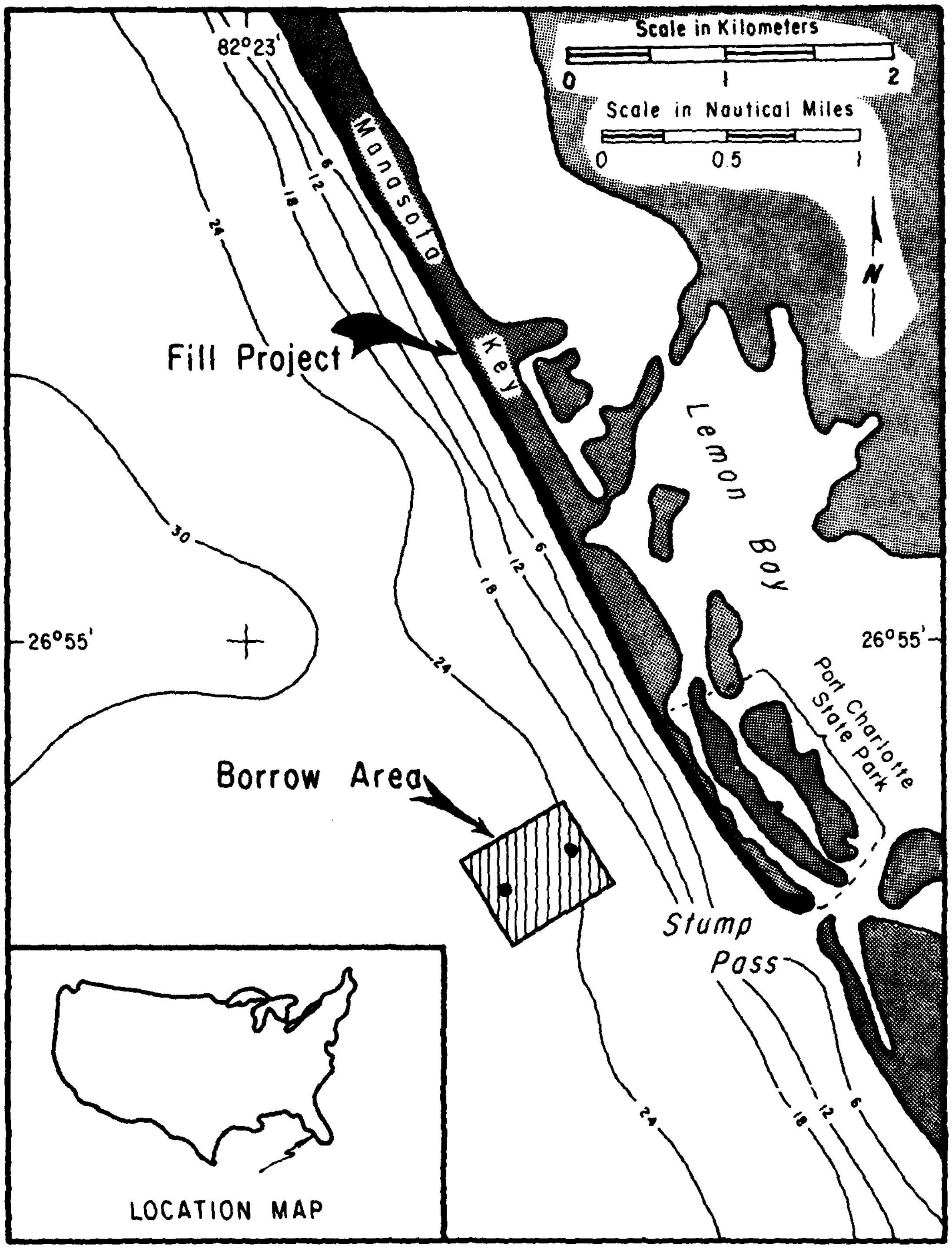

Figure 29. Location and bathymetry, Charlotte County, Fla. (depth contours in feet)

Table 37

Project Specifications, Charlotte County, Fla.

	Port Charlotte State Park	Northern Project
Beach and Fill Characteristics		
Initial fill volume		
Beach	53,900 m^3	177,100 m^3
Storm dune	26,950 m^3	None
Renourishment volume	7,600 m^3/year	34,600 m^3/year
Fill length	1.8 km	4.5 km
Fill elevation (above mlw)		
Beach berm	1.5 m	1.5 m
Dune	2.7 m	No dune
Beach width increase	9.0 m	9.0 m
Average volume loss	7,600 m^3/year	34,600 m^3/year
Borrow Site Characteristics*		
Site area	0.41 km	
Average water depth	8.7 m	
Average thickness	6.0 m	
Sediment volume	2,400,000 m^3	
Distance from project	1-5 km	
Additional Considerations		
Initial cost	$1,057,000	$849,000
Annual cost	$150,300	$221,800
Other project features	Terminal groin	Port Charlotte
	Sandstones frequently crop out on bottom	

* Additional exploration in borrow area is needed.

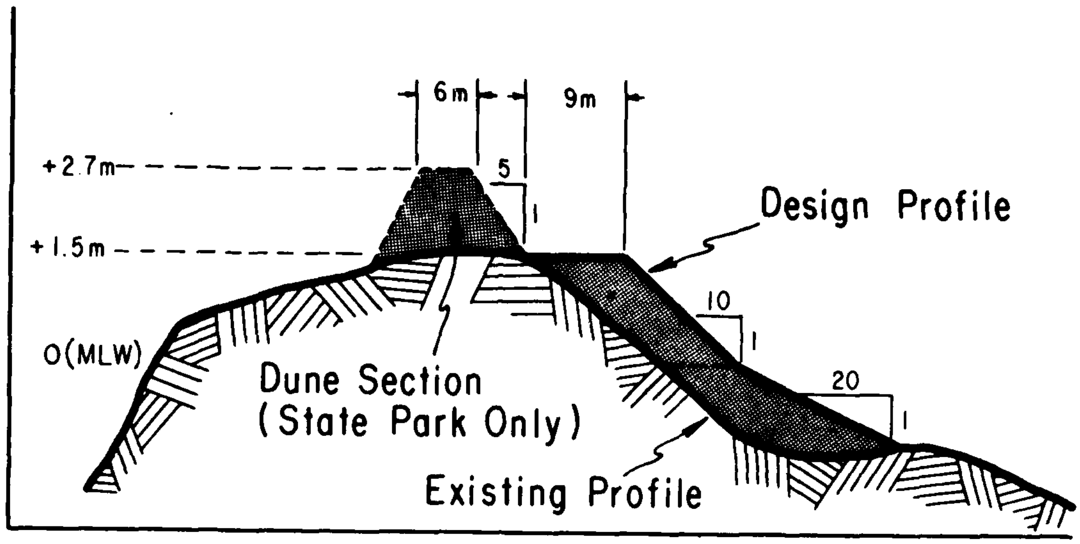

Figure 30. Beach fill section, Charlotte County, Fla.

study area. In 1972 (updated in 1974) the University of Florida Coastal and Oceanographic Engineering Laboratory completed a study of beach erosion at Port Charlotte State Park, which extends for 1.8 km northward of Stump Pass. In 1971 local interests funded a study of the northern 6.3-km reach of the county shoreline.

75. The near offshore region is characterized by massive outcrops of steeply dipping, soft sandstones. Sandy deposits characteristically fill swales between the outcrops or thinly mantle the rock surfaces. These unconsolidated sediments often contain a large percentage of fine silt and clay and would be unsuitable for use as beach fill.

76. Seismic and coring explorations for potential offshore borrow sources were initiated, and 12 Vibracore samples were taken offshore of the beach at areas where the geophysical records indicated possible sand accumulations. Two of the cores contained clean to slightly silty quartz sands, and the area surrounding these locations (Figure 29) seemed most promising for development as a potential sand source.

77. Native beach deposits are characterized by the composite of 29 surface sand samples obtained along four profile lines. Native and borrow sediments are compared for beach fill calculations for the entire

6.3-km-long study reach (Table 37). Fill requirements, however, are tabulated separately for the Port Charlotte State Park and the northern 4.5-km-long segment of the proposed improvement area. The composite gsd's and beach fill calculations are presented in Tables 38 and 39, respectively.

Table 38

Composite Grain Size Distributions, Charlotte County, Fla.

Size mm	Size ϕ	Native Beach (29 Samples)	Borrow (4 Samples)
13.45	-3.75	0.5	0
9.51	-3.25	0.9	0
4.75	-2.25	3.0	0
2.00	-1.00	7.6	8.0
0.84	0.25	19.2	25.2
0.42	1.25	30.8	40.2
0.25	2.00	40.1	57.9
0.15	2.75	59.5	82.0
0.07	3.75	95.9	92.3
Phi mean		1.63	1.32
Mean (mm)		0.32	0.40
Phi sorting		1.63	1.63

Table 39

Beach Fill Model Calculations, Charlotte County, Fla.

Fill factor (R_A)	1.00
Renourishment factor (R_J)	0.83

Lido Key, Fla.

78. Lido Key is located on the Gulf Coast of Florida in Sarasota County. This crescent-shaped barrier island is about 4 km long, has an average elevation of 2.4 m mlw, and is separated from the other sandy barriers that form the county's 56-km-long coastline by New Pass to the north and Big Sarasota Pass to the south (Figure 31). In 1964, the Jacksonville District was authorized to study beach erosion for the entire county. An interim BEC study report was prepared first for the Lido Key portion of the county because of the severity of erosion there and the apparent readiness of the city of Sarasota to undertake a Federal project (U. S. Army Engineer District, Jacksonville 1969). No prior Federal beach erosion studies had been made for the area, but the Corps of Engineers had studied New Pass and recommended navigation improvements. The improvements were authorized in 1964 and this project has periodically provided beach fill to the key. In 1964, 94,000 m^3 were dredged from the pass and placed along the northern tip of Lido Key. Maintenance work in the pass provided nourishment material for the southern half of the project in 1974 and 1977.

79. The erosion problems at Lido Key can be traced primarily to the low barrier island's location with respect to the paths of major storms and hurricanes and to the considerable development of the area over the past 20 years. This development has effectively "frozen" the acceptable shoreline locations, which over the past 40,000 years have continually been submerged, emerged, and reshaped. Hurricanes and major tropical storms from the southeast strike the general region about once every three years, while winter storms are from the northeast. The current trends are that these storms cause accretion of sand at the tips of the key and erode the central 3-km-long segment. Potential flood damage on the key during storms is great.

80. The restoration plan (Table 40) recommended nourishment of the central 1.9 km of Lido Key with 483,000 m^3 of sand and periodic nourishment supported by Federal aid for a 10-year period. It was also recommended that local interests be permitted to construct part of the project

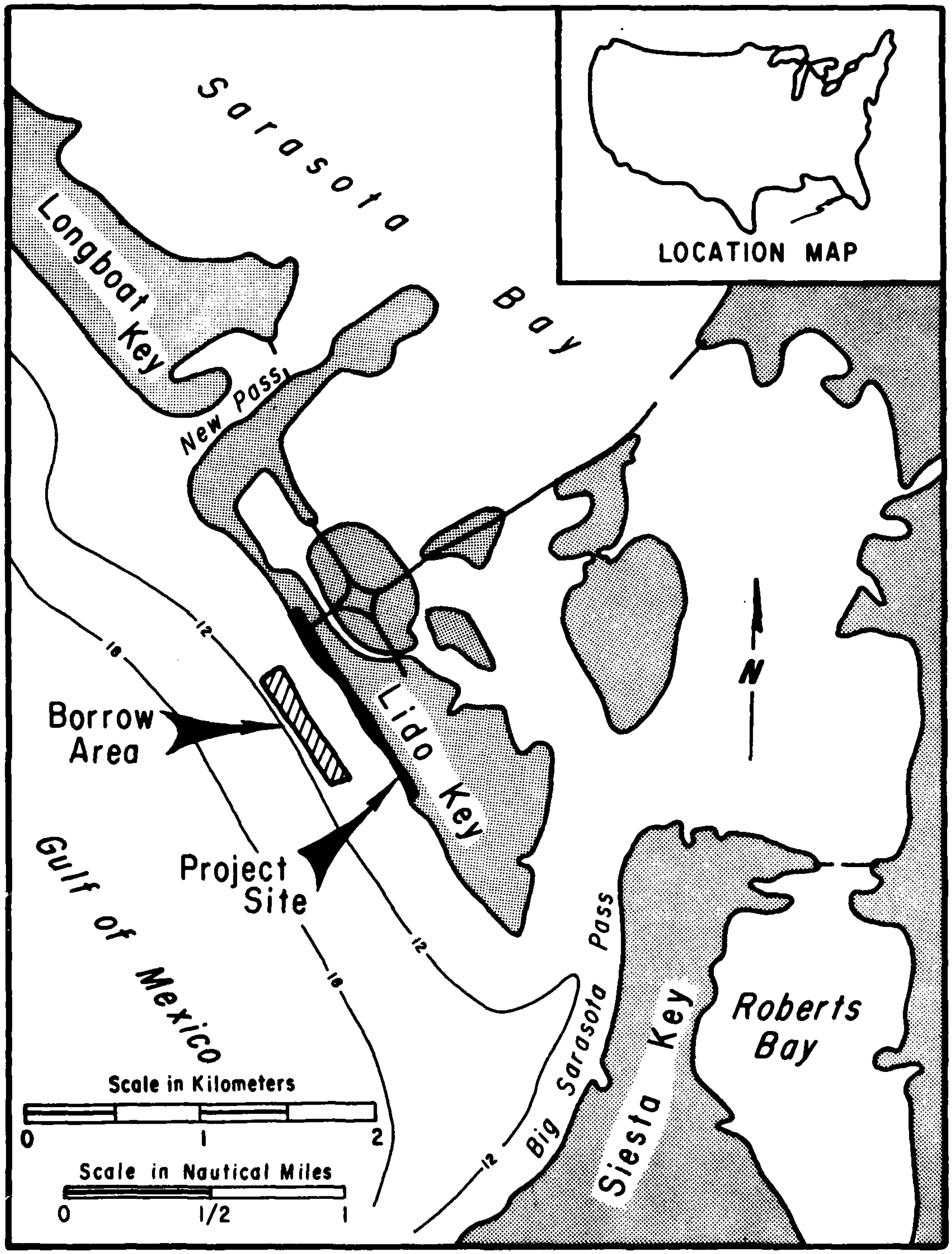

Figure 31. Location and bathymetry, Lido Key, Fla.
(depth contours in feet)

Table 40

Project Specifications, Lido Key, Fla.

Beach and Fill Characteristics	
Initial fill volume	483,000 m^3
Renourishment volume	51,000 m^3/year
Fill length	1.9 km
Fill elevation (above mlw)	1.5 m
Beach width increase	38-m berm
Average volume loss	42,600 m^3/year*
Average recession rate	2.5 m/year*
Borrow Site Characteristics	
Site area	0.6 km^2
Average water depth	4.2 m
Average thickness	6 m
Sediment volume	3,420,000 m^3
Distance from project	0.5 km
Dredging limitations	None
Additional Considerations	
Initial cost	$674,000 (1968)
Annual cost	$101,800 (1968)
Monitoring planned	Yes
Other	Most work has been completed locally with some Federal reimbursement

* Along eroded study reach.

and receive credit toward the local share of costs for the total project. Furthermore, it was estimated that sufficient quantities of suitable beach fill could be obtained from the shoal areas adjacent to New Pass and Big Sarasota Pass.

81. Local authorities initiated the fill project in 1969-70 and built the northern half with sand obtained from a borrow source located directly offshore (Figure 31). The composite gsd's for these borrow sediments appear in Table 41 and are compared with native sediments in Table 42 for beach fill calculation purposes. The southern half of the project was subsequently nourished in 1974 and 1977 with 187,000 m^3 and 287,000 m^3 of sand dredged from the navigation project at New Pass. The 1974 fill was piled on the beach and shaped to project dimensions while the 1977 material was placed as a "bulb" of sediment extending offshore to be shaped by natural processes. The performance of the fill (Figure 32) is being monitored to evaluate these methods of beach nourishment.

Treasure Island, Fla.

82. The initial emergency restoration of 2.8 km of Treasure Island Beach was made in 1969 following recommendations by the Jacksonville District in accordance with the general and detailed Design Memorandum for Treasure Island beach restoration (U. S. Army Engineer District, Jacksonville 1968). This document was produced in cooperation with the Board of County Commissioners of Pinellas County, Fla., and followed two previous beach erosion control studies by the Corps completed in 1953 and 1966.

83. Pinellas County is located on the Gulf Coast of Florida about midway along the peninsula and extends about 63 km northward from Tampa Bay entrance to the mouth of the Anclote River. The county coastline consists of numerous barrier islands (keys). Treasure Island is in the southerly half of the county (Figure 33), runs generally northwest-southeast, and is bounded by Johns Pass and Blind Pass on the north and south, respectively. The island is a popular resort area with easy bridge access for the public. Beach erosion measures were proposed to

Table 41

Composite Grain Size Distributions, Lido Key, Fla.

Size mm	Size ϕ	Native Beach (22 Samples)	Borrow (4 Cores)
4.75	-2.25	4.1	0.0
2.00	-1.00	12.0	3.1
1.00	0.00	19.5	5.0
0.42	1.25	26.5	9.9
0.25	2.00	30.4	10.2
0.18	2.50	45.0	17.5
0.15	2.75	52.1	40.8
0.12	3.00	70.8	80.1
0.07	3.75	98.4	99.5
Phi mean		1.38	2.73
Mean (mm)		0.38	0.15
Phi sorting		1.83	0.33

Table 42

Beach Fill Model Calculations, Lido Key, Fla.

Fill factor (R_A)	>7.0
Renourishment factor (R_J)	3.40

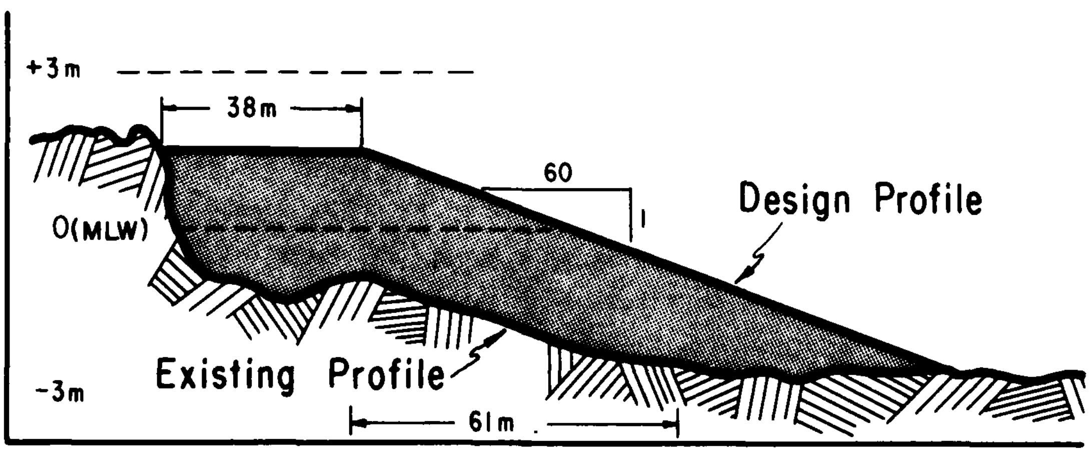

Figure 32. Beach fill section, Lido Key, Fla.

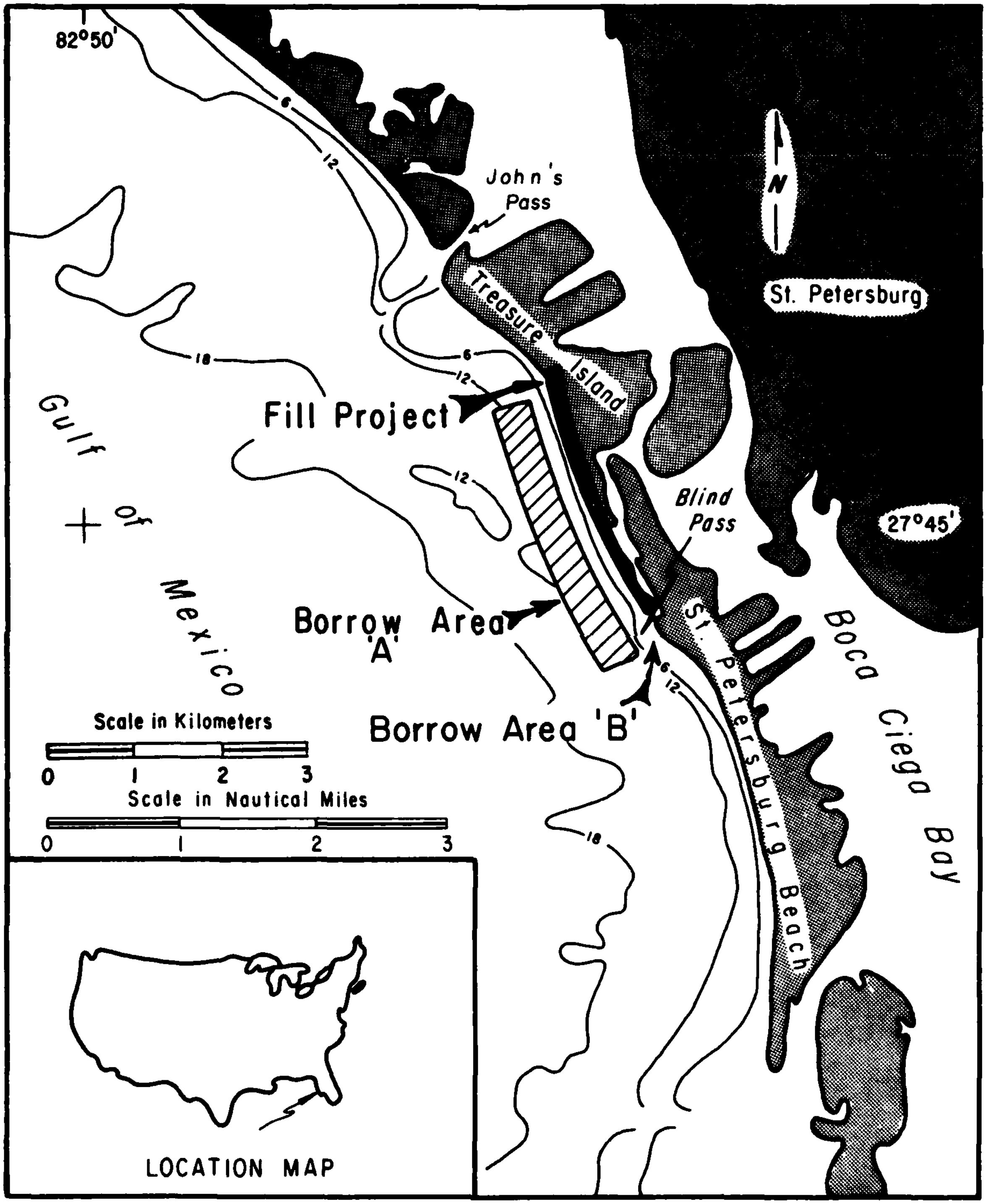

Figure 33. Location and bathymetry, Treasure Island, Fla. (depth contours in feet)

protect the area from flooding and high waves anticipated during design hurricane conditions. Cost benefits were therefore based on prevention of property damage and enhancement of value rather than on public usage.

84. Erosion losses from the area prior to the 1969 beach restoration (Table 43) were estimated to be approximately 27,000 m^3/year. In 1969, 608,000 m^3 of sand were placed on the beach (this volume includes volumes for both emergency and planned restoration purposes) (Figure 34). Blind Pass was excavated during construction to provide 14 percent of the fill sediments, to improve tidal circulation in the back bay, and to increase access to the bay for boaters. Blind Pass will require continued maintenance and may be responsible, in part, for the accelerated erosion losses reported for the southern half of the project since its completion. In the period of August 1969 to April 1971, yearly losses of sand from the northern and southern halves of the project were 8.2 m^3/m/year and 29.6 m^3/m/year, respectively, versus the 8.9 m^3/m/year predicted for the entire project reach. Renourishment was required in 1971 and 1972 with 57,350 m^3 and 119,350 m^3 placed during these respective years to counteract the rapid erosion. The Design Memorandum prepared for the third periodic nourishment (U. S. Army Engineer District, Jacksonville 1975) included a proposal for constructing two groins to stabilize beach erosion. These groins would each be about 100 m long, with one located on the north side of Blind Pass and the other approximately 700 m northward. With the groins, future renourishment requirements are estimated to be 30,800 m^3/year, whereas a yearly need of 88,550 m^3 is estimated without structures.

85. Two sources for sand were investigated (U. S. Army Engineer District, Jacksonville 1966), and results from this investigation have been used in the design of the original restoration project and all subsequent renourishments. Both areas are offshore in the Gulf of Mexico with Borrow Area A (Figure 33) lying approximately 1 km offshore from the beach and extending about 2 km parallel to Treasure Island. Borrow Area B constitutes an area of shoals located in front of Blind Pass. Seventeen core samples were taken in Borrow Area A and two from Borrow Area B. The composite textural data and fill model data appearing in

Table 43

Project Specifications, Treasure Island, Fla.

Beach and Fill Characteristics

	Treasure Island Beach
Initial fill volume	321,860 m^3
Renourishment volume	30,800 m^3 (groins)
	88,550 m^3 (no groins)
Fill length	2.3 km
Fill elevation (above mlw)	1.8 km
Beach width increase	12.2 m
Average volume loss	30,800 m^3/year

Borrow Site Characteristics

	Area A (Offshore)	Area B (Blind Pass)
Site area	0.5 km^2	0.1 km^2
Average water depth	4.0 m	1.0 m
Average thickness	4.3 m	Not available
Sediment volume	2,100,000 m^3	50,000 m^3/year
Distance to project	1.0 km	0.2 to 2.0 km

Additional Considerations

Initial cost	$1,228,000
Annual cost	$181,000
Other project features	2 groins proposed
Monitoring planned	Yes
Fill history	1969 initial placement 608,300 m^3
	1971 first renourishment 57,350 m^3
	1972 second renourishment 119,350 m^3

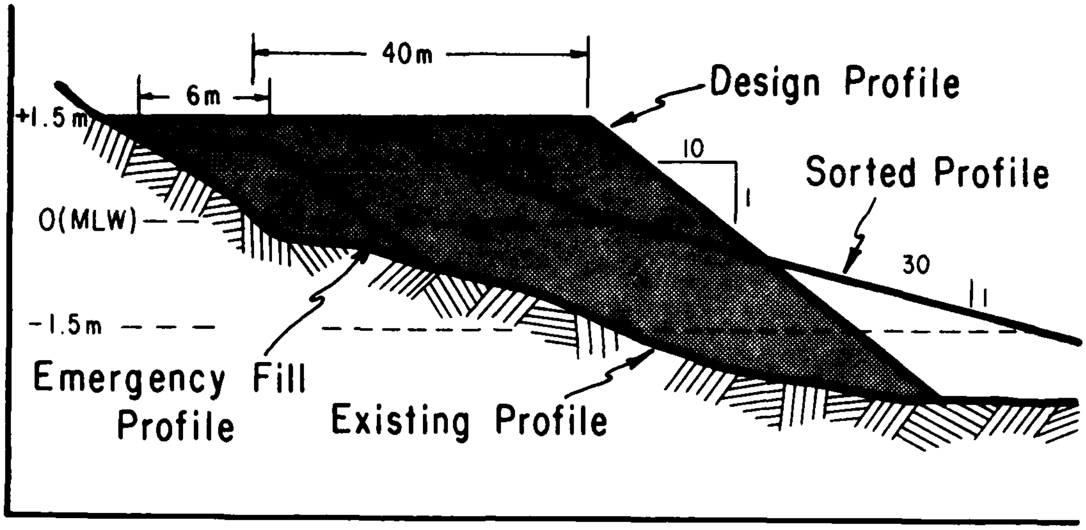

Figure 34. Beach fill section, Treasure Island, Fla.

Tables 44 and 45 were determined from gsd's of sands sampled in 1966 within the potential borrow areas and from along selected beach profiles.

Panama City, Fla.

86. The Panama City beaches are located in Bay County, Fla., along the northern margin of the Gulf of Mexico. They extend from the Panama City Harbor entrance through Shell Island westward for about 29 km to Philips Inlet (Figure 35). This coastline has retreated steadily due to erosion since at least 1856. However, until recent times, the area could boast of low, broad sandy beaches backed by a sparsely vegetated line of fore-dunes followed by a line of stable dunes with heavier vegetation of oaks, palmettos, and various shrubs. The oceanfront is vulnerable to direct wave attack from frequent storms and hurricanes. Hurricanes have occurred within a 100-km radius of the area about every 3.8 years since 1899. Until the landfall of Hurricane Eloise in 1975, however, natural processes had been adequate to replenish most sediment lost during these storms. Waves and flooding caused by Eloise were extremely damaging and caused massive beach erosion, breaching of dunes and bulkheads, and extensive flood and structural damage to buildings, footings,

Table 44

Composite Grain Size Distributions, Treasure Island, Fla.

Size mm	Size ϕ	Native Beach (14 Samples)	Borrow A Offshore (51 Samples)	Borrow B Blind Pass (10 Samples)
9.51	-3.25	0	0	0
4.75	-2.25	0.5	0.1	0.1
2.00	-1.00	5.2	11.3	7.0
0.84	0.25	8.6	18.3	10.8
0.42	1.25	13.1	22.6	14.7
0.25	2.00	29.5	29.1	33.5
0.15	2.75	64.7	44.7	50.8
0.07	3.75	93.3	90.5	95.3
Phi mean		2.35	1.68	2.32
Mean (mm)		0.20	0.31	0.20
Phi sorting		0.95	1.83	1.03

Table 45

Beach Fill Model Calculations, Treasure Island, Fla.

	Borrow A	Borrow B
Fill factor (R_A)	1.13	1.02
Renourishment factor (R_J)	0.14	0.88

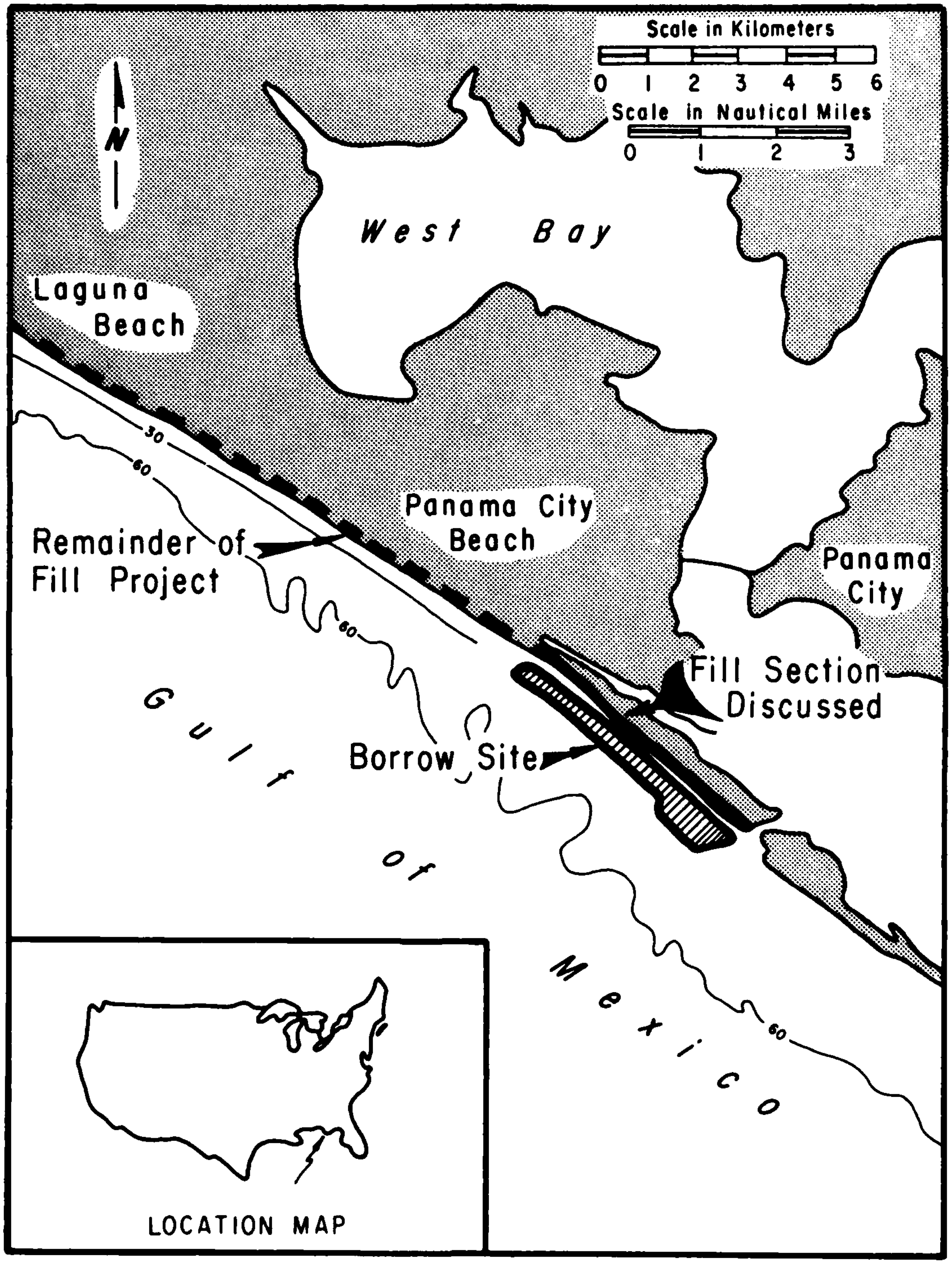

Figure 35. Location and bathymetry, Panama City, Fla. (depth contours in feet)

and roadways. Placement of emergency fills in 1976 was required for the most critically eroded locations. Borrow sediment for these fills was obtained from the seaward flank of the offshore bar. These materials contained a large percent of unstable clayey material.

87. Coastal setback laws passed by the State of Florida (1971) and by Bay County (1974) should reduce future storm-related structural damage in the area. The immediate effects of erosion were studied by the Mobile District (U. S. Army Engineer District, Mobile 1976) and their findings were published as an interim feasibility report. The report recommended placement of nearly 6 million m^3 of sand along the study reach followed by an estimated 72,000 m^3 annual renourishment (Figure 36, Table 46). These sediments are to be obtained from offshore sources in water depths equal to or exceeding 14 m in order to satisfy environmental restraints.

88. Unfortunately, there are no core data for sediments from the 14-m water depths recommended by the report. Therefore, the borrow textural data contained in Table 47 are for bottom sediments cored in 1971

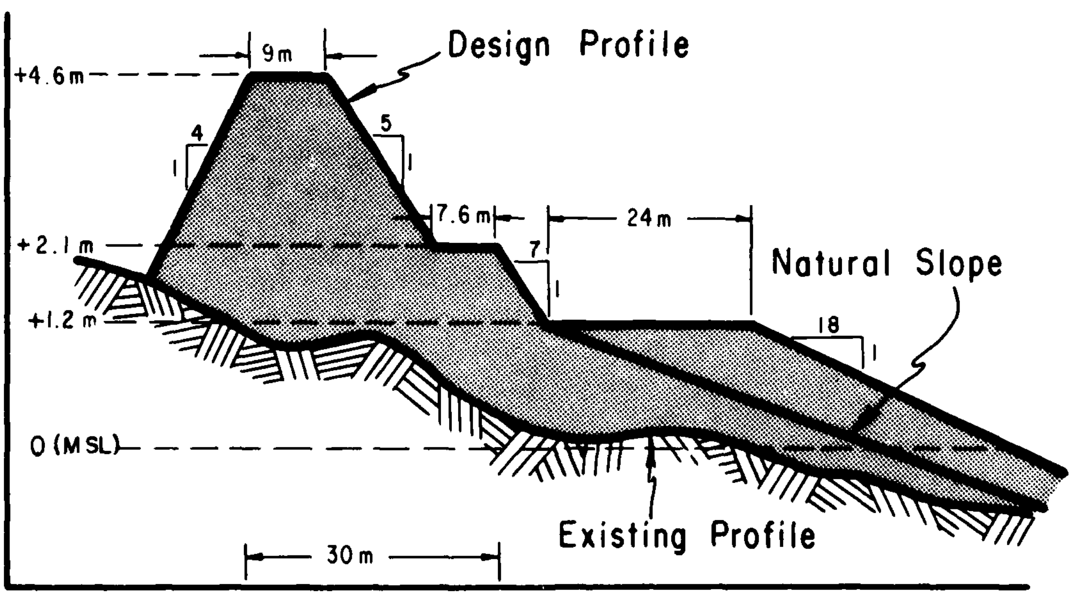

Figure 36. Beach fill section, Panama City, Fla.

Table 46

Project Specifications, Panama City, Fla.

Beach and Fill Characteristics	
Initial fill volume	5,977,000 m^3
Renourishment volume	71,896 m^3/year
Fill length	28.8 km
Fill elevations (above msl)	
Beach berm	1.2 m
Storm berm	2.1 m
Storm dune	4.6 m
Beach width increase	31.0 m
Average volume loss	55,300 m^3/year
Maximum loss for design storm	8.8 m^3/m/hour
Borrow Site Characteristics	
Site area	9 km^2
Average water depth	9.1 m
Average thickness	12.0 m
Sediment volume	108,000,000 m^3
Distance from project	3 to 30 km
Additional Considerations	
Initial cost	$19,550,000 (1976)
Annual cost	$1,704,000 (1976)
Monitoring planned	Yes
Other	Sand sources are anticipated to be required from 20-m water depths

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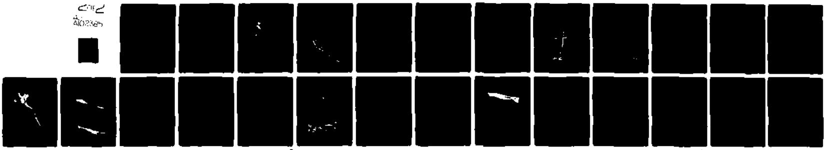

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from 5.5- to 12-m water depths for an area offshore of the eastern 4 km of the study area (solid project line, Figure 35). Beach textural data are also characteristic of this same reach. The beach fill and renourishment calculations are presented in Table 48. Additional offshore investigations are being initiated to adequately evaluate potential offshore sand sources.

Table 47

Composite Grain Size Distributions, Panama City, Fla.

Size mm	Size ϕ	Native Beach (35 Samples)	Borrow (16 Samples)
1.00	0	0	0.3
0.71	0.5	0.7	3.5
0.50	1.0	4.2	11.0
0.35	1.5	9.0	20.5
0.25	2.0	31.0	36.5
0.18	2.5	72.0	63.0
0.13	3.0	94.0	90.0
0.09	3.5	99.0	97.5
0.06	4.0	100.0	99.0
Phi mean		2.32	2.35
Mean (mm)		0.20	0.19
Phi sorting		0.58	0.55

Table 48

Beach Fill Model Calculations, Panama City, Fla.

Fill factor (R_A)	1.02
Renourishment factor (R_J)	1.10

89. A factor relating to this project is erosion in the study area that may be caused by entrance jetties built through Shell Island in 1934 to maintain the entrance channel to Panama City Harbor. A reconnaissance report dealing with this problem was prepared by the Mobile District under authority of Section 111 of the 1968 River and Harbor Act. This report contained preliminary findings that indicated about 4 km of the easternmost section of the study area downdrift of the jetties have experienced an erosion rate of about 2.1 m/year as compared with 0.4 m/year for the remainder of the study area, and that this increased rate is caused primarily by the jetties.

Newport Beach, Calif.

90. Erosion of the Orange County coastline from Surfside to Newport Beach (Figure 37) is the result of a perennial series of events, some man-made and some from natural causes. Prior to any improvements along the shore or in the tributary drainage area, the beaches were supplied and maintained primarily by sediments carried to the area during floods from the Los Angeles, San Gabriel, and Santa Ana Rivers. Construction of flood-control measures, shore protection works, jetties, and breakwaters altered the normal shore regimen to the extent that areas where adequate protective beaches formerly existed became seriously eroded. Two decades of relative drought conditions during the 1940's and 1950's also had an adverse effect on the supply of beach building sediments to the littoral stream.

91. Factors other than those above that contribute to the erosion problem are: (a) the geomorphic instability of Newport Beach's spitlike configuration in response to slight variations in the seasonal wave regimen, (b) an apparent increase in storms from the northwest that generate waves that intersect the shore at sharp angles and increase southerly drift, (c) an apparent decrease in Pacific storms from the southwest that generally cause littoral drift reversals to a northerly direction, and (d) effects of the Newport submarine canyon upon wave refraction and as a sink for littoral drift (U. S. Army Engineer District, Los Angeles

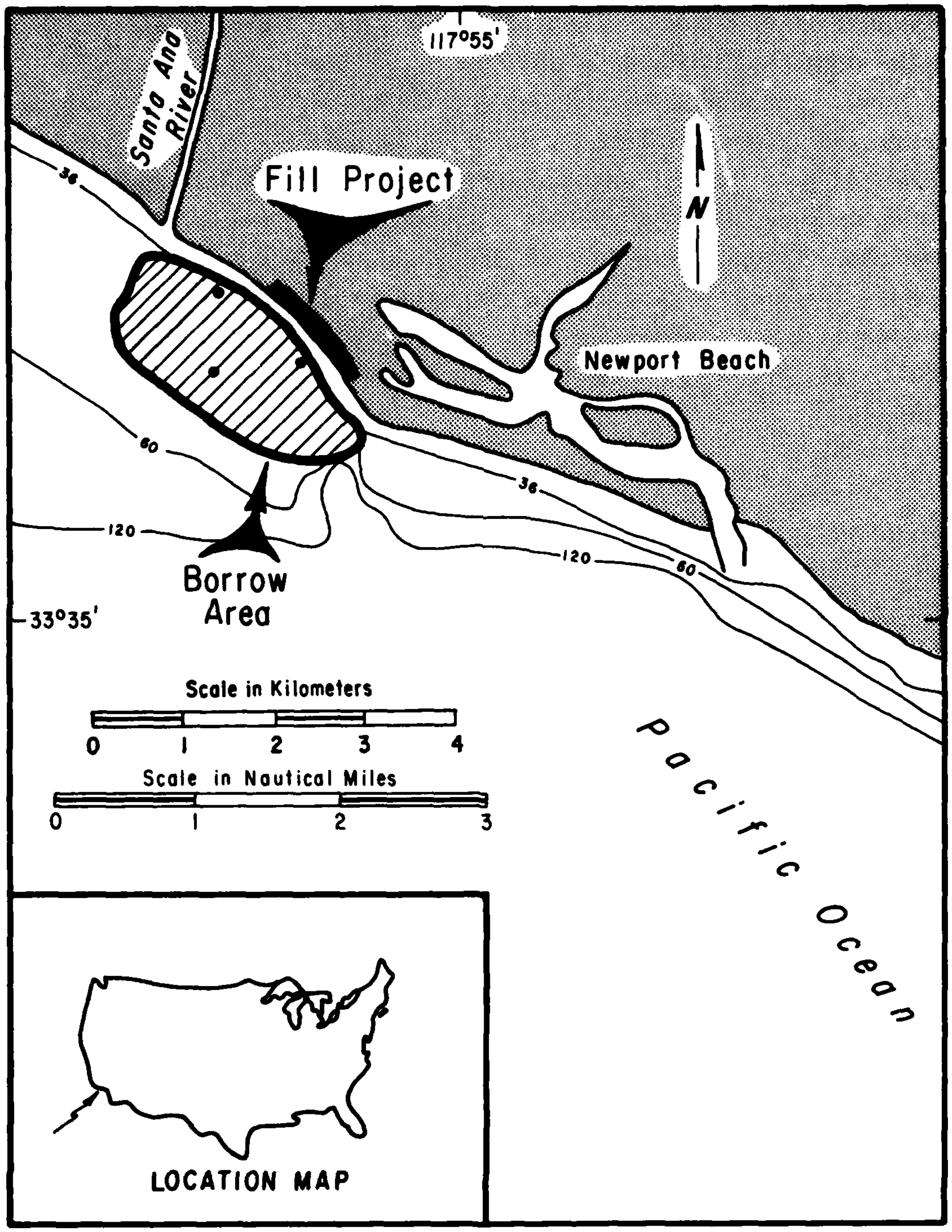


Figure 37. Location and bathymetry, Newport Beach, Calif. (depth contours in feet)

1969). The final problem of the Newport canyon acting as a sediment sink within the littoral zone is a problem shared by a number of littoral cells along the California coast.

92. The Orange County Beach Erosion Project (Figure 38) was authorized and approved in 1962 (Table 49). The portions of this project completed prior to 1970 included placement of beach fill at Surfside and Sunset Beaches in 1964 (3,040,000 m^3), placement of beach fill at Newport Beach in 1968 (558,000 m^3), and construction of 67- and 90-m-long steel sheet-pile groins at Newport Beach in 1968. The final stage of the project was to include additional fill and construction of four more rubble mound groins. Sediments for the beach fill were to be obtained from inland sources.

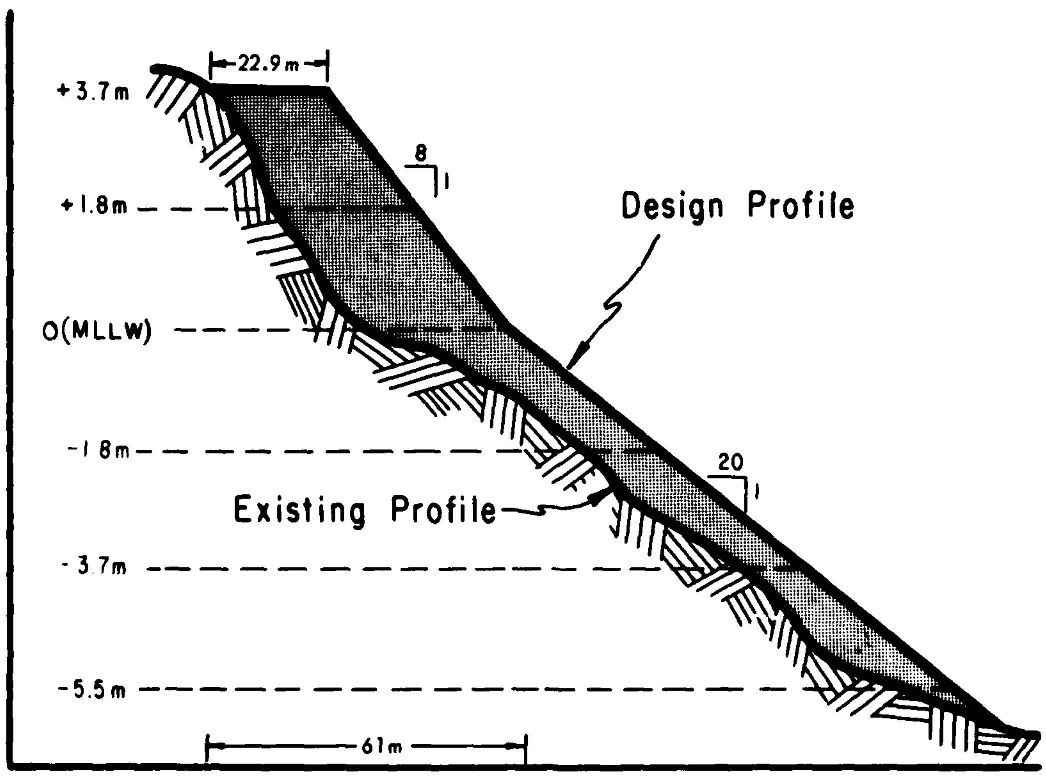


Figure 38. Beach fill section, Newport Beach, Calif.

Table 49

Project Specifications, Newport Beach, Calif.

Beach and Fill Characteristics	
Initial fill volume for beach	159,600 m^3
Renourishment volume	39,500 m^3/year
Fill length	1.1 km
Fill elevations (above mlw)	
Beach berm	2.1 m
Storm dune	4.5 m
Beach width increase	23.0-m average
Average volume loss	39,500 m^3/year (with groins)
Borrow Site Characteristics*	
Site area	5 km^2
Average water depth	12-20 m
Average thickness	3.0 to 18 m
Sediment volume	15,000,000 to 90,000,000 m^3
Distance from project	1 to 5 km
Additional Considerations	
Initial cost	$600,000 (1969)
Annual cost	$35,000 (1969)
Other project features	4 rubble mound groins
Monitoring planned	Yes

* Additional exploration in borrow area is needed.

93. In 1974, CERC conducted a sediment and seismic survey of the inner continental shelf off southern California to locate sand resources suitable for use in beach restoration (Field 1974). A fairly large area northwest of Newport canyon was included in the study (Figure 37) and was found to contain a large volume of sand. The composite gsd of sediment samples from three cores obtained in 1974 appears with a native beach composite (U. S. Army Engineer District, Los Angeles 1970) as Table 50, and these sediments are compared for beach fill purposes in Table 51.

94. The beach fill calculations from Table 51 appear quite promising, but a detailed offshore investigation would be necessary to adequately assess the full potential of these sand reserves. It appears that very large reserves will be required to maintain beaches along this highly active coastline, and that offshore sand sources will ultimately be required to supply these needs as traditional land sources are exhausted or become economically unavailable.

Redondo Beach, Calif.

95. Redondo Beach is located within the same littoral cell as Newport Beach, and erosion problems there have occurred for many of the same general reasons as described for Newport Beach in the previous section. These reasons include natural wave and weather phenomena coupled with man-made changes. These changes have been to the shoreline and drainage basin areas whose periodic flooding once supplied most of the sediment to the littoral system.

96. By 1954, it was apparent that BEC measures were necessary. Studies of the problem were undertaken, and plans for nourishment of the 2.4 km of beach south of Redondo Harbor (Figure 39) were prepared by the U. S. Army Engineer District, Los Angeles (1966). Both inland and offshore sources of sand were considered. The Chief of Engineers instructed the Los Angeles District to use offshore sources for the authorized project, as the project provided an opportunity to experiment with techniques of direct placement of fill from offshore. In consonance with this

Table 50

Composite Grain Size Distributions, Newport Beach, Calif.

Size mm	Size ϕ	Native Beach (48 Samples)	Borrow (12 Samples)
2.83	-1.5	0.1	0
2.00	-1.0	0.2	0
1.41	-0.5	0.6	0.7
1.00	0	1.6	3.3
0.71	0.5	4.5	7.0
0.50	1.0	12.0	26.0
0.35	1.5	24.9	48.6
0.25	2.0	41.8	82.5
0.18	2.5	58.3	92.4
0.13	3.0	75.9	93.4
0.09	3.5	90.0	96.1
0.06	4.0	97.2	100.0
Phi mean		2.23	1.40
Mean (mm)		0.21	0.38
Phi sorting		1.02	0.64

Table 51

Beach Fill Model Calculations, Newport Beach, Calif.

Fill factor (R_A)	1.00
Renourishment factor (R_J)	0.58

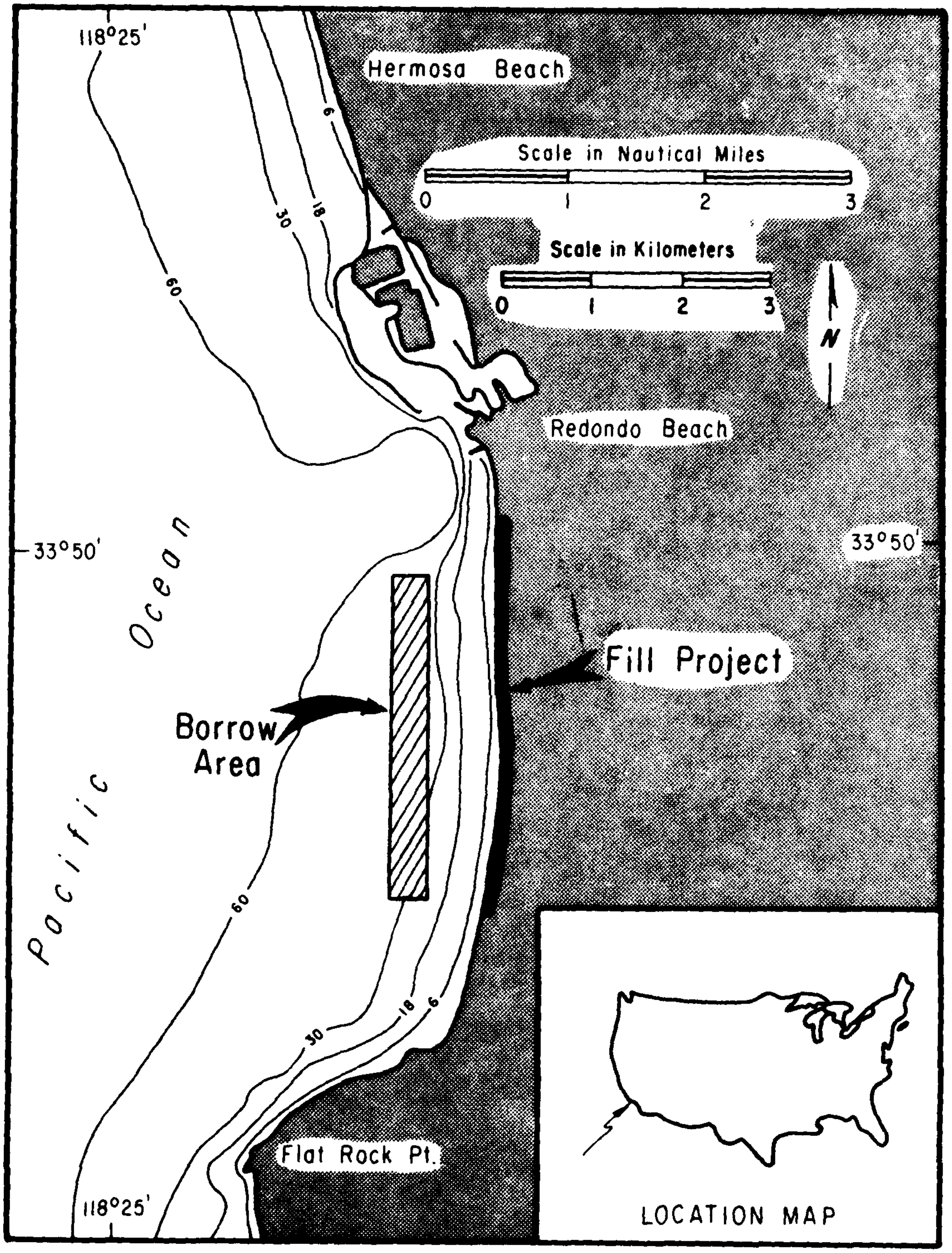


Figure 39. Location and bathymetry, Redondo Beach, Calif. (depth contours in feet)

instruction, investigations were made to determine if enough suitable sand was available seaward of the -9 m contour immediately fronting the project. Geophysical surveys of the area were made, followed by the collection of 29 core samples from areas of apparent promise as determined by analysis of the seismic records. The investigations indicated that the area would provide at least 1,900,000 m^3 of sand between the -9 and -18 m contours, and that this sediment would be excellent beach nourishment material (Fisher 1969). Plans and specifications were prepared (Figure 40, Table 52) and the project was begun in December 1967.

97. Dredging was performed using a standard 94-cm hydraulic suction dredge that had been modified for the job by extending the ladder to 27 m and fabricating a special water-jet suction head. The dredge was held on location using three anchors set in a triangular pattern, so that adjustment of wire lengths with winches allowed the dredge to pivot across the area during a cut and then advance to the next cut. Using

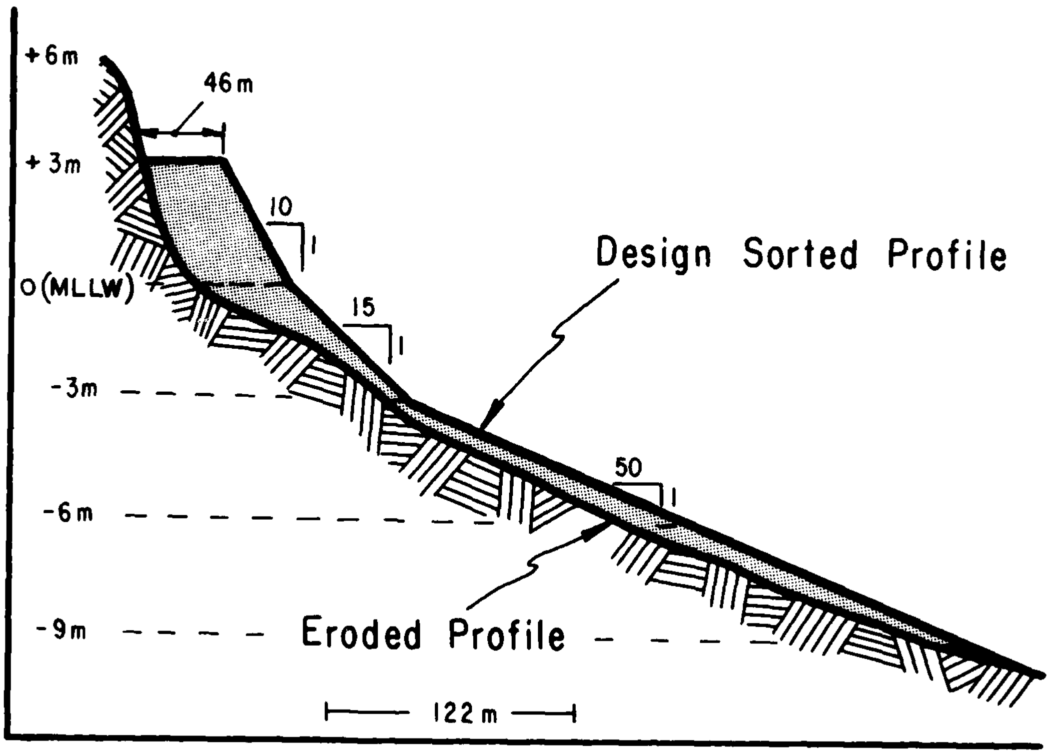


Figure 40. Beach fill section, Redondo Beach

Table 52

Project Specifications, Redondo Beach, Calif.

Beach and Fill Characteristics	
Initial fill volume	1,064,000 m^3
Renourishment volume	7,600 m^3/year
Fill length	2.4 m
Fill elevation (above mllw)	
Beach berm	3.7 m
Beach width increase	46.0 m
Average volume loss	7,600 m^3/year
Borrow Site Characteristics	
Site area	1.6 km^2
Average water depth	9 to 18 m
Average thickness	4.6 m
Sediment volume	7,360,000 m^3
Distance from project	2 km
Additional Considerations	
Initial cost	$1,302,000 (1966)
Annual cost	$123,000 (1966)
Other project features	1 rubble mound groin
Monitoring planned	Yes

this method, a cut depth of about 6 m was possible, providing maximum sand recovery with minimal swinging and moving of the dredge.

98. The sand slurry was pumped directly to the beach through a submerged pipeline. The project was completed in 92 days, and the design volume of 1,064,000 m^3 of sand was placed on the beach at a unit cost of $1.40 per cubic metre.

99. Table 53 shows composite gsd's for the borrow material as cored, for the placed fill as sampled on the beach, and for native beach sands collected prior to nourishment. Table 54 contains beach fill model

Table 53

Composite Grain Size Distributions, Redondo Beach, Calif.

Size mm	Size ϕ	Native (8 Samples)	Offshore (58 Samples)	Placed Fill (7 Samples)
4.56	-2.25	0	2.9	0.3
2.00	-1.00	0.1	13.2	0.8
0.84	0.25	12.5	23.1	6.7
0.59	0.75	25.0	30.9	25.9
0.42	1.25	43.0	55.2	51.7
0.30	1.75	77.7	69.5	76.7
0.25	2.00	86.3	74.9	83.0
0.18	2.50	93.6	78.2	89.1
0.15	2.75	95.8	83.1	93.7
0.07	3.75	99.4	90.0	99.3
Phi mean		1.15	1.10	1.32
Mean (mm)		0.45	0.47	0.40
Phi sorting		0.40	1.70	0.78

Table 54

Beach Fill Model Calculations, Redondo Beach, Calif.

	Offshore Borrow	Placed Fill
Fill factor (R_A)	1.32	1.15
Renourishment factor (R_J)	0.18	1.20

calculations. It is interesting to note that the placed fill is better sorted and of a finer mean grain size than the offshore sediments. The sorting difference may reflect losses of finer sediments during the dredging and placement phases of the project. This type of sorting loss of fine sediments has been observed for many other dredging operations. The mean grain size difference is more difficult to explain, but may reflect sampling procedures, and inability of the pumps and suction head to pick up coarser grain sizes during dredging, or that coarser sizes are heavier and tend to be buried during placement of the slurry on the beach.

Indiana Dunes, Ind.

100. The study of erosion problems along the Lake Michigan shore from the Indiana-Illinois border eastward to Michigan City, Ind., was authorized in 1970 under Section 110 of the River and Harbor Act of 1962. A reconnaissance investigation of the effects of Michigan City Harbor structures on adjacent shorelands was completed in 1971 by the Chicago District under the authority of Section 111 of the 1968 River and Harbor Act (Figure 41). This report concluded that these structures do interrupt littoral drift in the harbor area and are responsible for substantial updrift accretion northeast of the harbor and downdrift erosion to the southwest. The report recommended construction of groins and an artificial beach, with periodic nourishment, as the most desirable plan of protection (Figure 42, Table 55).

101. Field studies conducted between 1966 and 1973 by CERC along this shoreline provided native beach sand texture and wave data. The Chicago District undertook offshore sand investigations in 1972 to locate suitable borrow areas for fill sediment. Table 56 summarizes the combined results of these investigations (U. S. Army Engineer District, Chicago 1975). Table 57 contains beach fill model calculations obtained from the comparison of the texture of these sediment sources.

102. With normal lake levels, the study area is characterized by gently sloping beaches, hard packed at the water's edge, that stretch about 60 m to massive sand dunes. These dunes generally exceed 50 m in elevation and extend inland as stabilized wooded dunes for as much as 3 km. The origin of these physiographic features reflects processes active during the last phase of Pleistocene glaciation and the subsequent postglaciation interval. Over the past 14,000 years, a series of lake levels resulted in the reworking of glacial sediments by wind

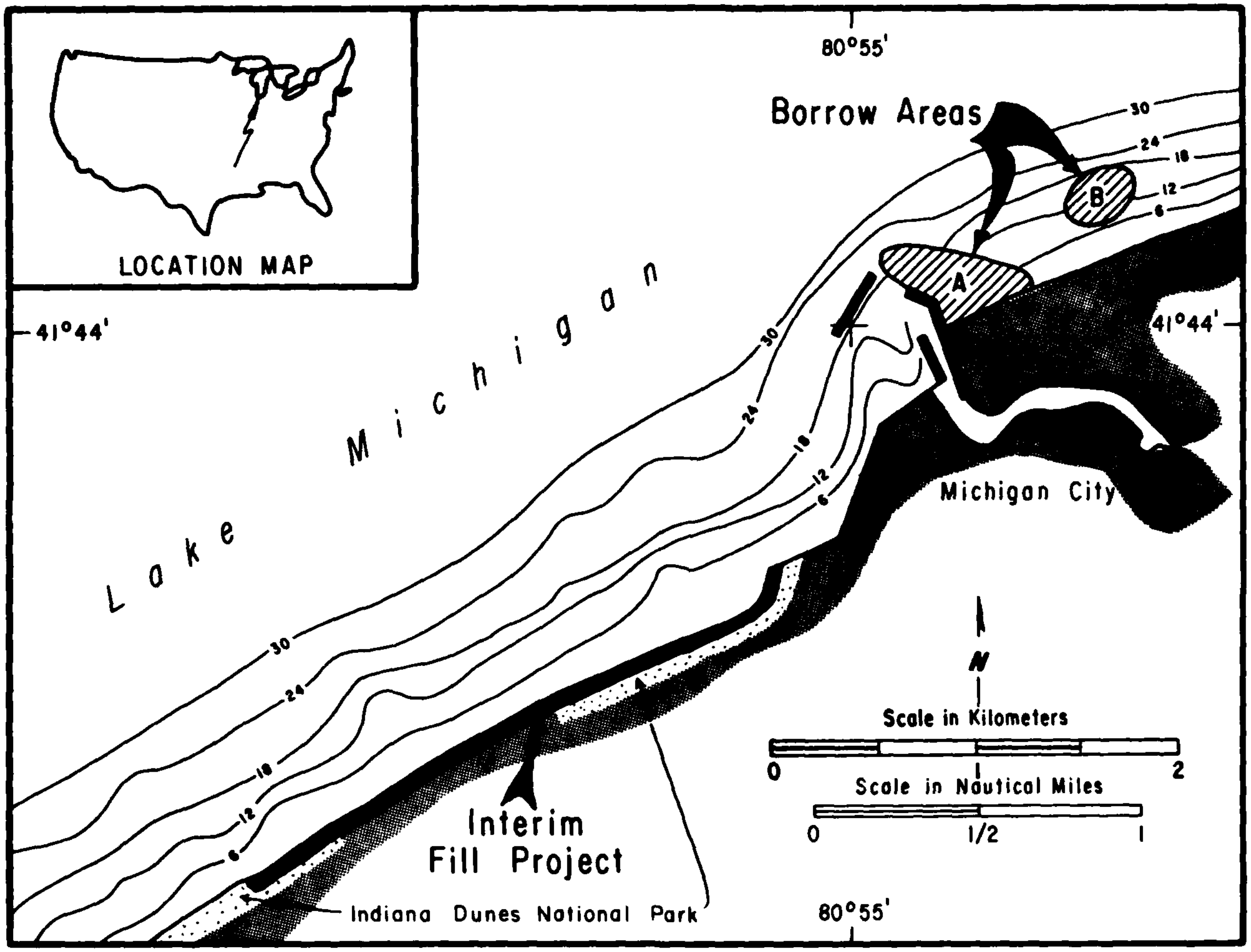
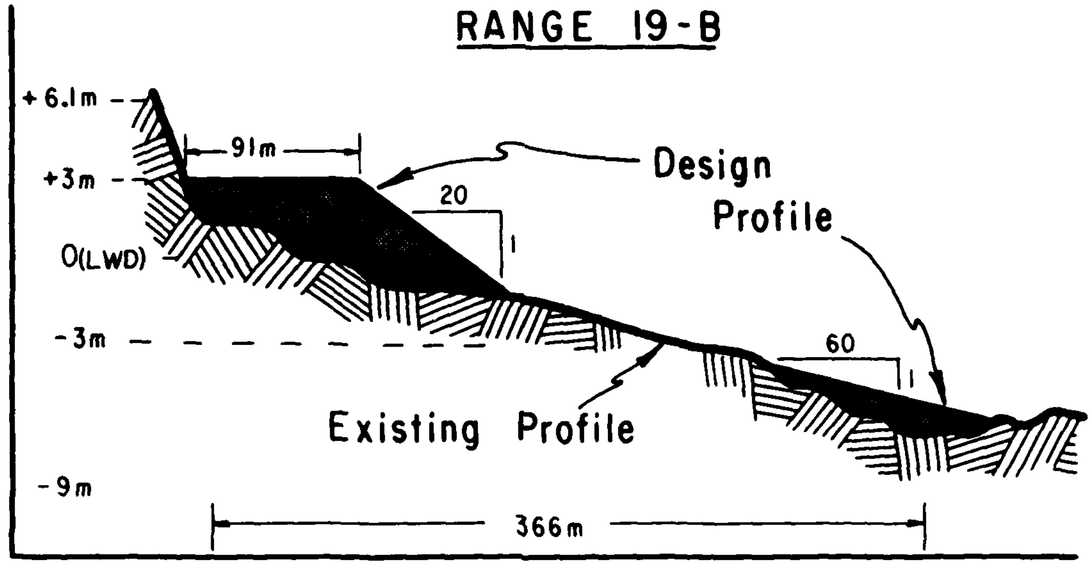


Figure 41. Location and bathymetry, Indiana Dunes, Ind.
(depth contours in feet)

A



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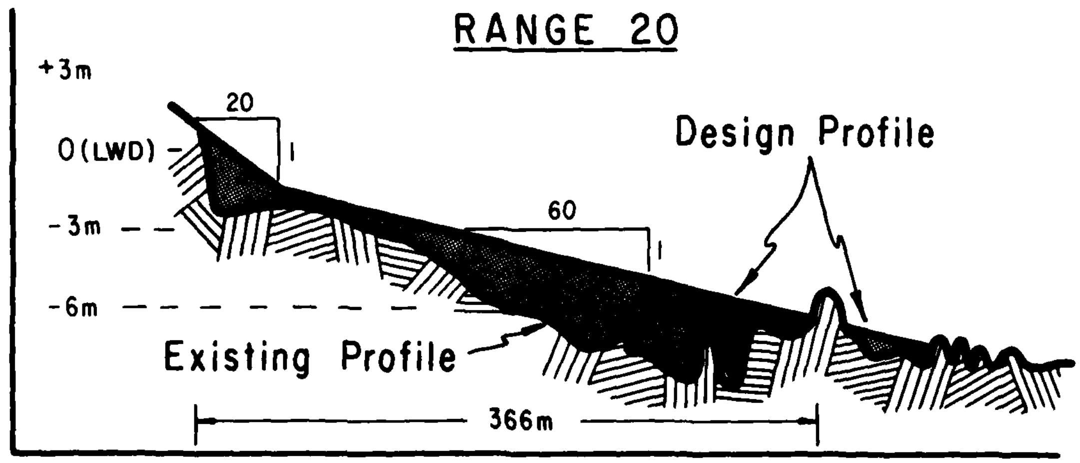

Figure 42. Beach fill sections, Indiana Dunes National Park, Ind.

Table 55

Project Specifications, Indiana Dunes, Ind.

Beach and Fill Characteristics		
Initial fill volume	1,300,000 m^3	
Renourishment volume	130,000 m^3/year	
Fill length	3.83 km	
Fill elevation (above LWD)	3.0 m berm	
Beach width increase	49 m	
Average volume loss	145,500 m^3/year	
Average recession rate	0.9 m/year	
Borrow Site Characteristics*		
	Borrow A	Borrow B
Site area	0.9 km^2	0.65 km^2
Average water depth	5.3 m	5.8 m
Average thickness	2.9 m	2.1 m
Sediment volume	2,600,000 m^3	1,400,000 m^3
Distance from project	7.6 km	9.0 km
Additional Considerations		
Initial cost	$7,393,000 (1975)	
Annual cost	$934,200 (1975)	
Monitoring planned	Yes	

* Additional exploration in borrow areas is needed.

Table 56

Composite Grain Size Distributions, Indiana Dunes, Ind.

Size mm	Size ϕ	Native Beach (131 Samples)	Borrow A (8 Cores)	Borrow B (6 Cores)
5.66	-2.5	0	0.2	0.3
2.00	-1.0	0	0.9	2.0
0.84	0.25	2.7	2.2	6.7
0.59	0.75	6.0	4.3	10.7
0.42	1.25	16.0	7.4	17.3
0.30	1.75	40.0	12.6	21.9
0.21	2.25	67.0	35.5	58.2
0.15	2.75	87.0	81.6	75.2
0.13	3.00	93.2	90.8	95.2
0.07	3.75	99.9	97.1	98.4
Phi mean		1.99	2.35	1.98
Mean (mm)		0.25	0.20	0.25
Phi sorting		0.71	0.50	0.83

Table 57

Beach Fill Model Calculations, Indiana Dunes, Ind.

	Borrow A	Borrow B
Fill factor (R_A)	3.75	1.02
Renourishment factor (R_J)	2.25	0.83

and water and creation of three roughly parallel ridge sequences within the Indiana Dunes National Lakeshore region. These ridges became stabilized and protected by beaches made up of a coarse sediment of reworked morainal debris.

103. During this century structures at the Michigan City Harbor entrance, coupled with recent high lake levels, have accelerated erosion

to the northeastern portion of the Indiana Dunes National Park and to adjoining public lands. This erosion removed the coarse sand that had formed the beaches and exposed finer sediments of wind and glacial-lake origin. The erosion problem was severe enough that in 1974 a 127,000-m^3 emergency fill and a 1-km revetment were placed along the eastern 4-km segment.

104. Future erosion predictions are highly dependent upon the rates of lake level change and the texture of sediments exposed to wave and current action. The shore is now in the area of fine, windblown dune sands, and thus erosion has intensified. On the other hand, recent rates of lake level rise appear to have slowed or perhaps ceased, causing a reduction in erosion rates. An erosion rate of 0.9 m/year was used for engineering design purposes in the 1975 Interim Report, in which the recommended restoration plan called for placement of 1,300,000 m^3 of fill along 4.8 km with an additional 130,000-m^3 annual renourishment to maintain project dimensions (Figure 42). Erosion of the 1974 emergency fill has been about as predicted; thus the predicted erosion rate appears reasonable for future project designs.

Presque Isle, Pa.

105. Presque Isle Peninsula is a compound recurved sand spit extending into Lake Erie toward the northeast for about 10 km (Figure 43). It is owned and managed by the Commonwealth of Pennsylvania as a state park and encloses the harbor of Erie, Pa. The peninsula has a long history of erosion and was breached at least five times during the first 100 years of the period since 1824, when Erie Harbor was originally authorized as a Federal deep-draft navigation project. In 1946, the 79th Congress passed Public Law 727, which authorized Federal participation in the cost of shore protection works recommended to stabilize the neck of the peninsula and prevent deterioration of the harbor (U. S. Army Engineer District, Buffalo 1973).

106. The peninsula is of glacial origin, but during recorded history complex natural forces have been responsible for moving it eastward

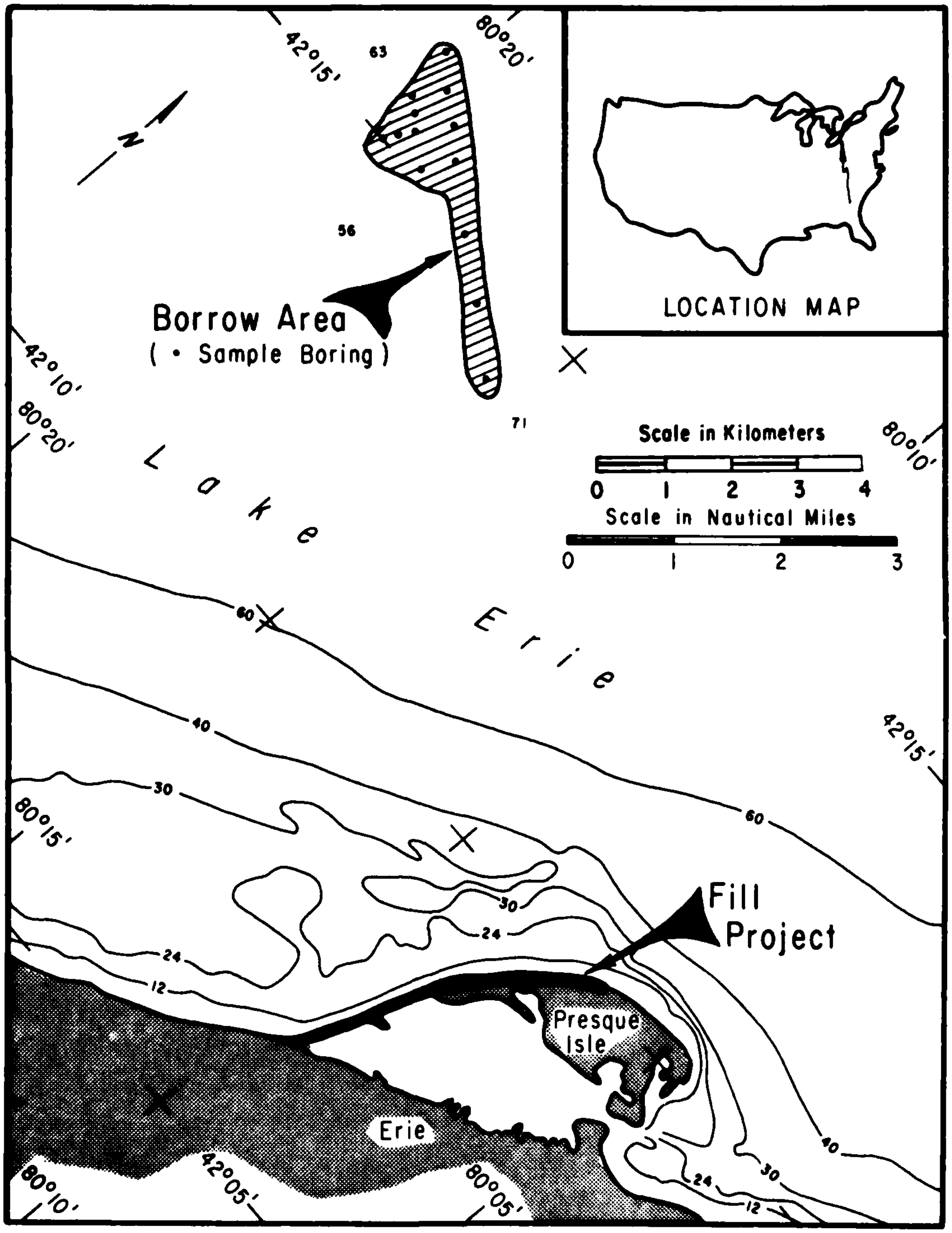

Figure 43. Location and bathymetry, Presque Isle, Pa. (depth contours in fe...)

to its present location. These forces include: (a) littoral currents bearing beach material that deviate lakeward as they move down the spit, (b) wave action that turns the spit inward to form a hook shape toward the east, (c) northeasterly storm winds that cause the building of sand ridges, and (d) interactive wind and vegetative processes that build and stabilize the dunes and form soil.

107. Historically, sand required for the growth of Presque Isle was derived from the 35 km of Lake Erie shoreline between Conneaut, Ohio, and Erie, Pa. Currently this section of shoreline is inadequate to maintain the beaches along the peninsula's neck. This situation is due largely to numerous man-made structures projecting into the lake, fronting dune, and cliffed areas, and to the many local streams that once supplied granular material to the littoral zone but have since eroded through available unconsolidated glacial deposits down to resistant underlying shales.

108. Numerous restoration efforts have been attempted at Presque Isle. The first major project was completed in 1956 and included the construction of 31 groins and 4.2 km of bulkhead and placement of 3,154,000 m^3 of fill. Since 1956 there have been at least 16 renourishment and emergency fill events resulting in the placement of an additional 1,178,000 m^3 of sand. In general, nourishment has not been a successful solution to Presque Isle's erosion problems. Most of the sand that has been placed has been finer grained than native beach sediments and considered unstable according to current beach fill design criteria. An exception was 34,000 m^3 of an especially prepared coarse sand mixture that was placed in 1966 between groins 2 and 3 in the neck region. This fill was monitored and exhibited more stable characteristics than adjacent groin compartments filled with finer sediment.

109. The 1974 Water Resources Act provided emergency funding to extend Federal participation in beach nourishment for five more years at Presque Isle. A new plan is currently being completed (Table 58, Figure 44) for protecting the peninsula. This plan calls for construction of three detached, rubble-mound breakwaters opposite beach areas of critical erosion, and placement of an additional 1,300,000 m^3 of

Table 58

Project Specifications, Presque Isle, Pa.

Beach and Fill Characteristics	
Initial fill volume	1,300,000 m^3
Renourishment volume	137,000 m^3/year
Fill length	8.5 km
Fill elevation (above LWD)	3.0-m berm
Beach width increase	20-m berm
Average volume loss	117,000 m^3/year
Borrow Site Characteristics	
Site area	5 km^2
Average water depth	17 m
Average thickness	0.2 m (min)
Sediment volume	1,000,000 m^3 (min)
Distance from project	12 km
Additional exploration	Needed
Additional Considerations	
Initial cost	$21,203,000 (1973)
Annual cost	$1,701,000
Other project features	Series of offshore breakwaters located along 3-m-depth contour
Monitoring planned	Yes
Other	Clay layers often present

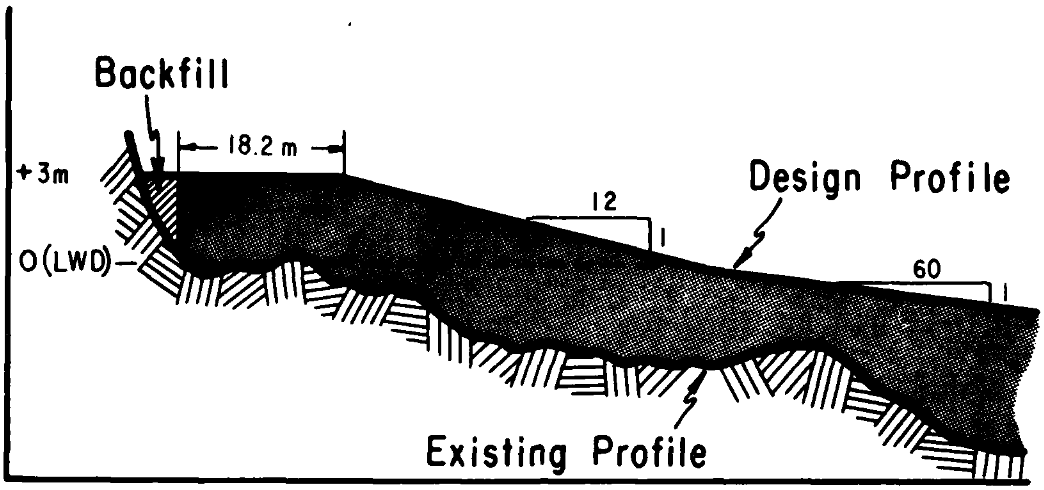

Figure 44. Beach fill section, Presque Isle, Pa.

suitable coarse grained fill with an anticipated yearly renourishment requirement of 137,000 m^3. Investigations to evaluate possible borrow sources of adequate and economic fill materials are also under way. Offshore (Figure 43) and onshore areas have been sampled by the Buffalo District while nearshore sand sources are being delineated by CERC. The composite grain sizes and the beach fill calculations for the project are presented in Tables 59 and 60, respectively.

Table 59

Composite Grain Size Distributions, Presque Isle, Pa.

Size		Native	Borrow
mm	ϕ	Beach	(12 Cores)
2.00	-1.0	3.0	7.0
1.41	-0.5	5.5	8.0
1.00	0	5.9	11.5
0.71	0.5	7.2	18.0
0.50	1.0	14.5	32.0
0.35	1.5	27.5	55.4
0.25	2.0	46.0	77.0
0.18	2.5	68.5	90.0
0.13	3.0	84.0	96.0
0.08	3.5	96.5	100.0
0.06	4.0	99.5	100.0
Phi mean		2.05	1.30
Mean (mm)		0.24	0.41
Phi sorting		0.95	1.45

Table 60

Beach Fill Model Calculations, Presque Isle, Pa.

Fill factor (R_A)	1.05
Renourishment factor (R_J)	0.25

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Hobson, R. D.
Beach nourishment techniques : Report 3 : Typical U.S. beach nourishment projects using offshore sand deposits / by R.D. Hobson (Geotechnical Engineering Branch, U.S. Army Coastal Engineering Research Center). -- Vicksburg, Miss. : U.S. Army Engineer Waterways Experiment Station ; available from NTIS, [1981].
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Bibliography: p. 115-117.

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